NASA Administrator
Daniel S. Goldin

Steps To Mars II
Prepared Remarks
July 15, 1995

I want to start by thanking several of the people who contributed to this paper. I spoke with a lot of people in my search for a vision -- and a picture -- of the Mars journey.

I want to thank Chris McKay. I also want to thank some very talented people at NASA:

France Cordova,
Harry Holloway,
Wes Huntress,
Jeff Plescia,
John Kerridge,
and Michael Meyer.

Before I talk about going to Mars, I want to take you on a trip back in time. Let's go back to an ancient, violent age, 4-and-a-half billion years ago.

The Earth and Mars are forming in similar ways. They're red-hot, glowing with a boiling lava surface. For over a half billion years, they're bombarded with rocks and metals. There is no life. No living thing could withstand the heat and the pounding they're taking.

Finally, 3.9 billion years ago, the bombardment stops. The noise and the fury cease. There's just an occasional splashdown of one of the left-over small planetismals.

Both the Earth and Mars have cooled down. Their temperatures are below the boiling point of water. Polar caps are beginning to form. Rain falls continually as the steam in their warm atmospheres condense. This leaves behind thick atmospheres rich in carbon dioxide and nitrogen.

Earth and Mars look very much alike. There are large bodies of water on both planets, formed from water steaming out of volcanoes and from impacting comets.

During this period, geologic features are developing on Mars that will be important billions of years later. Large impact craters and basins are forming, where sediments will later be deposited and preserved. These areas might later harbor traces of life, or life itself.

Volcanoes are erupting and emitting water vapor. The heat and water are forming hydrothermal circulation systems that could later generate metal mineral deposits. These systems could produce environments for life.

The intense bombardment by meteorites is forming a thick, loose rock layer -- a regolith. In the future, it might be the storehouse of subsurface water and ice.

Soon, the Earth will produce the first self-replicating molecules. These will assemble themselves into the first single-cell organisms. The long march toward intelligent life on Earth will begin.

The same process on Mars may be going on. But the result may be different. The result may have been a life form unlike anything we have on Earth.

Let's move forward from 3.9 billion years ago to 3.5.

Earth and Mars are beginning to diverge. The evolution of the Earth's surface and atmosphere is hugely affected by the fact that life has a foothold on the planet.

Mars is on a different path. Its evolution is being shaped almost exclusively by geophysical processes. Life, if it managed a foothold on Mars, couldn't survive on the surface. Surface life couldn't have withstood the change in climate. Mars is too small a planet to trap the heat needed to move its huge crustal plates. That slows down the renewal of the atmosphere through volcanic action.

So the Mars atmosphere begins to thin. The planet becomes dryer and colder. Ice is now the dominant form of water on the surface of Mars and below. Life languishes in shrinking pockets of warmth and liquid water.

Not so on Earth. Life flourishes on its warm, wet surface. On Earth, our fossil records go back 3-and-a-half billion years. They're fossils of algae that were found in Australia. The earliest beginnings of life before that are a mystery. We can't go back any further than 3-and-a-half billion years. Earlier relics of life were obliterated by constant change on the Earth surface.

That may not be the case on Mars. The fossils of chemical evolution -- if they exist -- could still be there. Because of the cold, arid climate of Mars, there is little erosion. Mars also lacks plate tectonics. So much of the planet's ancient crust has been preserved.

Early life on Mars could have fossilized quickly after dying, just like on Earth. But even when the surface of Mars became hostile to life, it remained benign for fossils. A fossil formed on Mars 3-and-a-half billion years ago is probably still sitting there. It may be encased in sedimentary rock, waiting for us to find it.

When we begin to dig on Mars, when we look through the layers of its crust, we'll look back through time.

It's widely believed that every living thing on Earth shares a common ancestor -- apparently, thermophyllic sulfur bacteria. Who knows what we'll find on Mars? We might discover traces of whole new kingdoms of life.

Maybe we'll learn that the same building blocks of life washed over both planets. We could find fossils of cells with elements of proteins similar to what's here on Earth. We could find that one fossilized cell that's the missing link between the two planets.

We might find actual life -- imagine that. We might find extant life in some specialized environment. It may be just below a few grains in translucent sandstone -- a microscopic greenhouse, as in Antarctica. We may find life buried deep in ancient sediments.

Any of these possibilities would be profound.

Mars may be our next destination in space. Its secrets, and what it could tell us about our own planet are intriguing. We've learned from our robotic travels that Mars is the likeliest planet to have developed life. It also has surface conditions the most like our own.

If Mars is humankind's next destination, we should launch in 2018. That's when it would take the least amount of energy to launch. We have time to plan. We have time to do it right.

Our goal should be a sustained presence on Mars, not a one-shot, spectacular mission. Emigration, not invasion.

During the 25th anniversary of Apollo, reporters asked me if I was going to announce a mission to Mars -- make a big splash. I said, "That's too easy." A one-shot spectacular isn't what we're after.

Apollo was old-think. It was brute force. We spent what would be $75 billion today, and we did it for eight years. We don't have that kind of money anymore. And that's not all bad.

The bad news is our budget was cut. The good news is it's forcing us to do things differently.

We're going to use new-think on our next piloted planetary mission. We'll be more efficient. We'll work with international partners, industry, government and academia.

We'll create economic opportunity on our way. We will develop space. Our rockets won't just take us to Mars. They'll open up the space frontier.

Unlike Apollo, we'll live off the land. The most successful expeditions on Earth didn't try to carry all their supplies with them. Lewis and Clark lived off the land, and that's what we'll do.

One set of choices is brute force versus sophistication. Brawn versus brains.

The other set of choices is this. We can lead the world, or we can sit on the sidelines and watch. Whether we go or not, Japan will be there in 30 years.

If we lead the world, we'll shape humankind's boldest adventure. But we have to start now. There is a lot of work to do. We should be pursuing two parallel paths right now. Robotic precursor missions, and human space flight.

Let me start with the robots. We're entering the second era of scientific, robotic Mars exploration with the Mars Surveyor program. It isn't a single mission. It's a continuing series of missions to fully explore the planet.

We're going to explore Mars carefully and systematically. We'll be bold, but not brash. This won't be a sprint mission. It will be a marathon.

Instead of rushing up to grab any rock or handful of soil we can, we'll get a better understanding of the planet. We'll figure out where it makes sense to take samples. We want to be smart before we go. That way, the samples we do bring back will tell us the most about Martian evolution, climate, water and other resources.

Our first job is to map the planet from orbit. We'll send small, low-cost orbiters to Mars in 1996, 1998 and 2001 to do that.

The first Global Surveyor will be launched in 1996 to map the geology and topography Mars. It will give us a start on a global geochemistry map.

The second in 1998 and the third in 2001 will give us that map and examine the atmosphere and climate. They'll also search for water in the atmosphere, on the surface and below the surface. These two orbiters will also complete the orbital communications network of three orbiters around the planet. Our landed missions will use the network to communicate back to Earth.

Building global maps from orbit was our first task. Our second task is to scout selected areas on the Martian surface with landers and rovers. We'll need to examine the local conditions, rock and soil types, the potential for water and other resources and signs of the planet's history.

We'll send a series of small, low-cost landers to many different areas of Mars. Then we'll determine the one or two sites we'll go to get samples.

The first of our landed missions is Mars Pathfinder in 1996, with the first Mars rover. It'll be a micro-rover, to provide mobility on the surface. Pathfinder is only the first. We'll send similar landed missions in 1998, 2001 and 2003. They will go to places as diverse as ancient cratered highlands and the planet's poles.

Landers will analyze soil and rocks. One of the things that will give us is ground truths for remote sensing measurements. The landers may also drill below the surface and look for permafrost.

When this phase of our robotic missions is complete, look at what we'll have done. We will have embarked on the search for clues to Martian ancient history and its present environment. We'll have searched for signs of past water and geological activity. We'll have looked for minerals that will tell us the story of ancient water and life.

We'll send more landers in 2003. They will be part of a large international effort to place a network of landers on the surface. This include a network of seismometers to understand the interior of Mars, and a network of weather stations to understand Martian weather and climate. Imagine getting a weather report from the polar station on Mars on the 11 o'clock news.

After we finish scouting the global diversity of the Mars surface with small landers, we'll be ready for a sample return mission. That could happen as early as 2005. Also by then, we hope the Mars Surveyor program will be involve Europe, Japan and Russia so we all go to Mars together.

A sample return is just the beginning. We'll need ways to move around and on the planet. We're looking at a range of things, from micro-rovers like on Pathfinder, to larger ones built with the Russians for more area coverage. We're looking at super-pressure balloons for very long aerial surveys of the planet. Maybe "hopper" techniques to move small landers from place to place are needed.

We're also interested in microlanders weighing only a few kilograms each and costing only $1M each. They could be deployed on approach to Mars or from orbit. They could even be sharp-pointed to penetrate many centimeters into the soil on landing. They could carry micro-cameras, and put micro-seismometers and weather-stations-on-a-chip on the surface of Mars.

The possibilities are fascinating. However we do this phase of exploration, one thing is certain. We won't just involve scientists and engineers. We will engage the world.

People will see on their televisions what our rovers see on the surface of Mars. People of all ages and backgrounds all over the world will fly with a balloon across the Martian surface. They'll look out over the Martian landscape like they were in a jet liner flying over the Earth.

The pinnacle of the Mars robotic exploration program will be a sample return.

We'll do all this efficiently and cheaply. The Mars Pathfinder is about 5% of the cost of Viking. In today's dollars, Viking would be over $3 billion. Pathfinder will cost about $270 million.

The Mars Global Surveyor will cost about $250 million, not the nearly 1 billion dollars the Mars Observer cost.

Let's fast forward to the next century and see what robots are doing in the future.

The most exciting thing they're doing is searching for life or traces of it. These fossils could be hidden within certain geological formations. The robots first have to seek out the right outcrops, guided by the mapping done earlier by orbiters.

They're also doing things to prepare for humans landing on Mars.

We've sent a robot fuel production plant to Mars. The international Mars I crew will use the fuel made on Mars to explore the planet. The plant sucks in Martian atmosphere and spew out rocket fuel. The fuel is stored on tanks on the surface of Mars. We've planted a radio beacon right next to the tanks for the astronauts to home in on as they approach Mars.

Robots will be doing many more things to prepare for the astronauts. They're building a water and wastewater recycling station the size of a barn. They're beginning to build the first infrastructures -- the first cityscape on Mars.

A convoy of robots is mapping Mars. They're drilling for water, hydrogen, metals, minerals and other resources.

Let me say a word about the search for water. We already know we can obtain limited quantities of water on Mars. We can get it from the atmosphere or polar ice caps. There may also be acquifers below the surface, with liquid water or ice.

With these robots is a mobile laboratory, where they'll deposit soil or rock samples for analysis. Slowly, a profile of the area where the robots are working emerges. Computers use the data to build a three-dimensional map. It's a tomographic map of the subsurface of Mars.

The robots are developing a picture of the subsurface structure -- layers of rock, the presence of water or ice, the thickness of sediments. Through chemical and mineralogic analysis, they are determining what the crust is made of. Why are certain types of rocks and minerals present?

As we move toward launching the human mission in 2018, here's what we'll have accomplished.

Our scientific exploration will have done detailed surveys of sites we want humans to examine for subtle and hard-to-find evidence of life. We'll have scoured the surface to find out exactly where water and other resources are most accessible.

When we've found the best sites and studied them with robots, the world will send the first human beings to the planet Mars.

We'll also have figured out how human beings can live and work in space for long periods, and many other things. We'll learn much of this aboard the international Space Station. In the process, we'll benefit the people on Earth. That's part of the new-think at NASA.

Let's fast-forward a little further ahead. It's 2018, just moments before the Mars I crew takes off for their two-year mission. It will take them six or seven months to get to Mars. They'll spend 30 days on the planet's surface. And they'll take 14 or 15 months to get back.

Right now, they're on the launch pad. When they get to low-Earth orbit, they'll transfer to the Mars vehicle. Once they're aboard, they'll talk to Mission Control in Houston. They'll also talk to Operation Centers in Kaliningrad, Bavaria and Tsukuba.

Before they blast off, let's take a moment. Let's look at what it's taken to get them to this point.

Before we send people into space for several years, we had to develop effective countermeasures to microgravity. That had tremendous benefits for elderly people suffering from osteoporosis on Earth.

We developed pre-screening procedures, to try to ensure a healthy crew. We can now identify medical conditions long before the symptoms become overt, so preventative measures can be used. Think about the effects of that on Earth. Think about what it would mean if we could identify and counteract a predisposition for cancer.

What if our astronauts do get sick on their trip? They can't take hospitals or doctors with them. So we had to develop chemical surgery techniques that can heal without scalpels or incisions. We put micro-machines into their bodies. Doctors will manipulate them from the ground.

Back in the 1990s, these little machines were only a concept in the minds of engineers and scientists at NASA and NIH. In 2018, they monitor what's happening in the body. They carry antibodies directly to a certain part of the body. They go to where a problem's begun and fix it.

That's made health care on Earth more accessible, cheaper, and less intrusive than it's ever been. The same kind of vital sensors we put into the bodies of astronauts to monitor, diagnose and treat them from the ground are used throughout the world.

They're used by surgeons to make prenatal corrections. They're used to continually monitor the elderly. If something goes wrong, a doctor is on the phone or another interactive system within minutes. People in rural areas in the United States and remote villages around the world have access to high-quality health care. We're diagnosed and treated in our homes. A hospital stay is the exception.

Of course we have a new rocket. Our reusable launch vehicle is opening up space. NASA doesn't run it -- industry does. Together, industry, government and academia are developing space.

Entrepreneurs are building industrial parks in space. The international Space Station isn't alone. It's just one in a constellation.

Our spaceship is self-diagnosing and self-repairing. Its systems incorporate micro- and nano-technology. It uses artificial intelligence to detect and report problems, and do simple fixes.

Our astronauts are taking along robotic assistants. They're capable of autonomous operation for exploration, science, and rescue tasks. They're controlled by advanced interfaces like voice recognition.

By 2018, we'll have done a much better job of integrating people and machines. We had to compensate for humans' limitations in absorbing and monitoring information. The Mars crew needs this kind of help because people on the ground won't be able to talk to them in real time. There's a more than 10-minute time lapse in getting a message from Mars to Earth and back.

Our crew will have to be able to absorb complex information quickly and make instant decisions.

I've taken you billions of years back in time. We've gone into the future to 2018, where Mars I sits on the launch pad, awaiting take-off. Let's take one more jump. Let's look at what the astronauts do once they arrive on Mars.

They're doing three kinds of activities.

One, they're doing things connected with past life on Mars. Two, they're doing things to support life in the present. And three, they're doing things for life in the future.

Let's start with life in the past. Suppose that robots have found a rock with what looks like a fossil in it. The next step is for humans to confirm that revolutionary finding. A team of astronauts is exploring the outcrop where the fossil was found. They are carefully selecting the most promising looking rocks, which they'll bring back to the base for study.

Several of our astronauts have gone down into an ancient, dried-out lake bed in the Southern Hemisphere to do a core drilling. They'll drill around the edges and into the center. They'll analyze the layers for clues to many things. The may find clues to what the atmosphere was like on Mars billions of years ago. Or more clues to the earliest forms of life.

The Mars I crew is also worrying about life in the present. They're making a place on Mars where humans can survive and grow and do research. They're also looking for Martian life, that's survived from ancient times, in a subsurface oasis.

They're also looking for water, more precious than gold. Thanks to the robotic precursor missions, they have a good idea where to start.

They're using subsurface, ground-penetrating radar -- kind of a high-tech divining rod. As scientists, they know that finding water would be important in understanding the past climate of Mars. As pioneers, they know it's critical to human survival.

The astronauts are also building hothouses. Humans didn't go to Mars alone. They went as a community of life forms, bringing with them seeds and plants grown on the trip. The studies done at the turn of the century on gravitropism -- the way plants react to gravity -- was an important step in the process. Eventually, we'll develop plants that can grow out in the open.

They also brought additional production plants to break down the Martian water into oxygen for breathing and hydrogen to use as fuel.

The third thing our crew is doing is looking toward life in future. They're beginning to assess whether terraforming is feasible. Whether it's possible for human beings to colonize Mars.

They're taking an inventory of the planet, much like the U.S. Geological Survey did in the Old West in the late 1800s.

Viking literally only scratched the surface. There's a lot we don't know about Mars. So they're taking inventory, building on what the robots have already done.

Is all the water that once was on Mars still there, or did some of it escape into space? If most of it escaped, reconstructing a habitable planet's going to be harder. If it's ice, or trapped in the ground, like oil is trapped on Earth, it'll be easier.

They're running studies and taking measurement to try to determine whether people could live on Mars for long periods. Can people live in one-third gravity with no ill effects? There's no magnetic field on Mars -- is that important?

They're also forwarding the search for planets around other stars. Our Solar System contains three Earth-like planets -- Venus, Earth and Mars. By better understanding the evolution of Mars, we'll get a better understanding of how planets in general form and evolve. This will help us in our search for solar systems around other stars.

As we search for the nearest 100 stars over the next 10 or 15 years, we may find a planet. We'll be better able to know whether we've found another Venus, Earth or Mars because of what our Mars I astronauts learn.

The next human crew to Mars will stay longer. They'll stay for nearly two years. They'll develop permanent habitats and grow a lot of their own food. They'll bring "hopper rockets" that will let them get anywhere on the planet.

Someday, there will be a colony on Mars. Humans will live and work on the Red Planet.

Someday after that, humankind will hear a brand new sound. A newborn baby's thin wail of life -- the fragile voice of the very first Martian.

Thank you.

Long version

Remarks Delivered by:
NASA Administrator
Daniel S. Goldin

National Planetary Society
Return to Mars II
Washington, DC
Transcript
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Thanks for coming on a hot, sweaty Saturday. I had a lot of trouble just functioning this morning. The program says I'm going to talk about the status of the space program, but I'm getting a little tired of talking about politics. I did that all week long, and this has been a very long week. So what I wanted to do today is talk about the vision. I want to continue the discussion on the vision. This is why I came to NASA.

I started working on the Mars expedition in 1962. It is now 1995. We need to really think about it. We have been working on a vision at NASA. We involved thousands of employees at NASA, the Congress and White House to come up with a vision statement we could publish. We came up with a five-year strategic plan. There are five enterprises. Alan Ladwig is developing a real strategic plan -- 25 years. A five-year strategic plan is totally inadequate. We hope to be sharing the new plan with the general public on the Internet. France Cordova next week will be putting out a new science policy on the Internet to get public comment. The whole purpose of this is to involve the public because the space program does not belong to the NASA employees or contractors or the people who work on our budget. It belongs to you. We have good people at NASA, but sometimes we get so involved in our day-to-day activity that we forget that the American public pays for the space program.

About a year ago, I went to the American Geophysical Union and laid out a challenge. I said, "What should be the next step in space? Put a base on the Moon? Put a research station on an asteroid? Go to Mars? We could build telescopes to search for planets around nearby stars if they exist. What should we be doing?" Three or four months ago, I went to Houston to an AIAA conference which dealt with the bio-medical aspects of space flight. I laid out a little fantasy of what the Mars mission might look like when I gave my speech. Today, what I'd like to do is take the next step and broaden it -- lay out a fantasy using a few fiscal facts, taking a lot of liberty, and make a rough sketch.

We'll look back in time 4 and a half billion years. I'll leave a little fact here and there from some of things we've done and seen through telescopes and talk about what might be on Mars. Then we'll fast forward to the year 2019 to describe what the Mars I mission might be doing. But more important than that, I'll lay the foundation of why we want to go to Mars. Then, I hope to expand upon this. I will show slides. I'm going to try and paint the picture in words.

Normally, I don't like to read speeches, but today I'm going to use it because we're experimenting with words, and I'd like to get a little feedback. So feel free to contact me electronically or directly or, if you're old fashioned like I am, take out a pen and write a note. I'm really interested because it's very important. I have complained to the scientific community that they only write for the highly educated. We need to expand our discussion with the broad American public and people around the world. I see we have a friend here from France. We also have friends here from Russia and other countries. It's important to all of us who deal with public funds to be more explicit. So this is an experiment. If you like the speech, tell me. If you don't like it, don't tell me you don't like it, tell me what you don't like so we can make some notes.

I don't have a lot of time because all I do is run up to the Hill. What I've been telling the Members of Congress lately is that I respectfully disagree with them for the first time. The space program should not be cut more. [Applause]. In my mind, in the last three to five years, every time there was a hiccup in some other budget, we pulled it out of the space program. Fortunately, there was room to cut the budget because we had to become more efficient in what we were doing. We had to become more focused. We had to redirect what we were doing. We had to get out of the operations business. We had to prioritize things. We had to get rid of the overhead. I want to tell you we can lose some activities, but on the other hand, I deeply believe there is intrinsic value in the space program, which the American people believe in.

What could happen in the months and weeks ahead? Maybe we'll have some problems. But deep down, I believe that we can't cut anymore. It's not a question of protecting jobs or this or that. The issue is that we have a program that's stunning -- I mean it's stunning. It takes your breath away. It's a program that's built on near-term activity, and it's a program that goes out 25-50 years. So we're there. Now, saying that, I want to talk about real fun things.

But before I do that, I'd like to give some recognition to some of the people I've had conversations with, who have shaped what I have here. One is Chris McKay, who's now in the Arctic, trying to do some relative planetology experiments to see what happens on Earth and on Mars. I also want to recognize France Cordova, Harry Holloway, Wes Huntress, Jeff Plescia, John Kerridge, Michael Meyer, Bob Zubrin and Diane Ballard. If I missed some, I'm sorry. These are people I've interacted with, and they've had wonderful thoughts about how to present all this.

Before I talk about going to Mars, I want to take you on a trip back in time.

Let's go back to an ancient, violent age, 4 and one-half billion years ago. The Earth and Mars are forming in similar ways. They're red hot, glowing with a boiling lava surface. For over a half billion years, they're bombarded with rocks and metals. There is no life. No living things could withstand the heat and the pounding they're taking. Finally, after 600 million years, 3.9 years ago, the bombardment stops. The noise and the fury cease. There's just an occasional splashdown of one of the leftover small planetoids. Both the Earth and Mars have cooled down. Their temperatures are below the boiling point of water. Polar caps are beginning to form. Rain falls continually as the steam in their warm atmospheres begins to condense. This leaves behind thick atmospheres rich in carbon dioxide and nitrogen. The Earth and Mars look very much alike. There are large bodies of water on both planets, formed from water steaming out of volcanoes and from impacting comets. During this period, geological features are developing on Mars that will be important billions of years later.

Large impact craters and basins are forming where sediments will later be deposited and preserved. These areas might later harbor traces or the very essence of life itself. Volcanoes are erupting and emitting water vapor. The heat and water are forming hydrothermal circulation systems that could later generate mineral deposits. These systems could produce environments to sustain life. The intense bombardment by meteorites is forming a thick, loose rock layer, a regolith. In the future, it might be the storehouse of subsurface water or ice. Soon, the Earth will produce the first self-replicating molecule. These molecules will assemble themselves into the first single-cell organism. The long march toward intelligent life on Earth is beginning. The same process on Mars may be going on, but the result may be different. We don't know. The result may have been a life form unlike anything on Earth.

Now let's move forward from 3.9 billion years ago to 3.5 billion years ago. Earth and Mars are beginning to diverge. The evolution of the Earth's surface and the atmosphere is largely affected by the fact that life has taken a foothold on our home planet. Mars is on a different path. It's just beginning to diverge from Earth. Its evolution is being shaped almost exclusively by geophysical, not biological, processes. Life, if it managed a foothold on Mars, couldn't survive on the surface. Surface life couldn't have withstood the change in climate on Mars. Mars is too small a planet to trap the heat needed to move its huge crustal plates, and that slows down the renewal of the atmosphere through volcanic action. So the Mars atmosphere begins to thin. The planet becomes dryer, colder. Ice is now the dominant form of water on the surface of Mars and below the surface. Life languishes in shrinking pockets of warmth and the remaining small pockets of liquid water.

Not so on Earth. Life flourishes on its warm, wet surface. On Earth, our fossil records go back 3.5 billion years. They're fossils of algae that were found in Australia. The earliest beginnings of life before that are still a mystery to us.

We can't go back any further 3.5 billion years. Earlier relics of life were obliterated by the constant change in the Earth's surface as a result of the tectonic activity. But this may not be the case on Mars. The fossils of chemical evolution, if they exist, could still be there, untouched. Because of the cold, arid climate on Mars, there is little erosion. Mars also appears to lack plate tectonics. So much of the planet's ancient crust is probably preserved. Early life on Mars could have fossilized quickly after dying, just like on Earth. Even when the surface of Mars became hostile to life, it may have become benign to fossils. If a fossil formed on Mars 3.5 billion years ago, it is probably still sitting there today. It may be encased in sedimentary material, just waiting for us to find it. When we begin to dig on Mars, when we look through the layers of its crust, we'll look back through a time machine.

It's widely believed that every living thing on Earth shares a common ancestor -- apparently thermophylic bacteria or heat-loving bacteria. Who knows what we'll find on Mars? We might discover traces of whole new kingdoms of originating life. Maybe we'll learn that the same building blocks of life washed over both planets simultaneously. We could find fossils of cells with elements of proteins similar to what's here on Earth. We might find that one fossilized cell that's the missing link between the planets. We might find actual life -- imagine that. We might find extant life in some specialized environment. It may be just below a few grains in translucent sandstone -- a microscopic greenhouse, as in Antarctica. We may find life buried deep in some of the ancient sediments on Mars. Any of these possibilities would profoundly affect how we think about who we are and why we're here.

Mars may be our next destination in space. Its secrets and what it can tell us about our own planet are intriguing. We've learned from our robotic space travels that it is the likeliest planet that might have developed life. This is the life zone. It has surface conditions the most like our own here on Earth. If Mars is humankind's next destination, the next launch date could be 2018. That's when it would take the least amount of energy to launch, over a 20-year period. We have time to plan. We have time to do it right. We have time to figure out how humans can live and work safely and efficiently in space on the international Space Station. We have time to figure out how to perform the mission for an affordable price that will allow a sustained presence in the solar system and not be a one-shot firecracker.

Final preparations need not start in earnest until the end of the first decade of the next century. But we can still make a landing in 2018 if we begin laying the groundwork now. Our goal should be a sustained presence on Mars and in the solar system and not a one-shot, feel-good spectacular mission. We are interested in emigration, not invasion. During the twenty-fifth anniversary [applause] of Apollo, reporters asked me if I or the President were going to announce a mission to Mars, make a big splash. I said, "That's too easy. A one-shot spectacular is not what we're after."

Now, Apollo was a one-shot sprint mission, but Apollo also met a national need -- beating the Soviet Union to the Moon. We did that, and I'm proud of it. I participated. It was brute force. We spent about 5% of the national budget to make this happen, but we had no vision beyond landing on the Moon so we went into the wilderness for 25 years. The program spent 5% of the national budget in today's terms and we did it in 8 years, which would be the equivalent today of spending 75 billion dollars a year in 8 years. This is not what we're about. People have this feel-good sense about Apollo and say, "Dan, why can't we do it again?" Well, now we're investing eight-tenths of one percent of the federal budget -- not 5% -- and we're into a marathon, not a sprint. We're into sustaining a presence in the solar system and in space, not a feel-good thing because we no longer have to beat the Soviet Union. We're going to partner with the Russians, the French, Germans, Japanese and others. We don't have that kind of money any more, and that's not all that bad.

The bad news is our budget is cut. The good news is it's forcing us to do things differently, more innovatively, more imaginatively, more cooperatively. We're going to use a new-think on our next piloted missions. We'll leverage 21st century technology. We've come a long way since Apollo, and we don't need brute force any more. We'll work with international partners, industry, government and academia. We'll take the time to develop and apply new technology before building the Mars rockets and equipment. We don't need to have a jobs program to go to Mars, we need to go to Mars. We'll create economic opportunity as we do. We'll develop space. Our rockets won't just take us to Mars, they'll open the space frontier. Unlike Apollo, we'll live off the land. The most successful expeditions in human history didn't try to carry all their supplies with them. Lewis and Clark lived off the land, and that's exactly what we will do. One set of choices is brute force versus technological finesse. We choose technological finesse. Rushing to Mars would be brute force. The use of brawn would drive the cost beyond anything that's tolerable.

Our other choice is this -- we in the United States can lead the world in this noble venture or we can buy a ticket and just watch. I submit that America is proactive. We should lead and not sit in the grandstands. If we lead the world, we'll shape humankind's boldest adventure. But we have to start now, there's a lot of work to do. We should be pursuing two parallel paths right now, and that's exactly what we're doing. These two parallel paths are robotics precursor missions and fundamental missions to understand the rigors of human space flight.

Let me start with the robots. We're entering the second era of scientific, robotic Mars exploration with the Mars Surveyor program. This isn't a one-shot program. We'll take advantage of every window to Mars to send a spacecraft.

It's a continuing series of reconnaissance missions to fully explore the planet Mars. We have other missions, but I'm not going to talk about those. I'm going to focus on Mars. We're going to explore Mars carefully, deliberately and systematically. We'll be bold, but not brash. This won't be a sprint mission, this is a marathon. Instead of rushing up to grab the first rock or handful of soil we can, we'll get a better understanding of the planet. We'll figure out where it makes sense to take samples. We'll want to be smart before we go. That way, the samples we do bring back will tell us the most about Martian evolution, climate, water and other resources.

Our first job is to map the planet from orbit. Towards this end, we'll send small, low-cost orbiters to Mars in '96, '98 and 2001 to do that. The first Global Surveyor will be launched in '96 to map the geology and topography of Mars. I'm not really thrilled with the spatial resolution yet, but it will give us a broad picture. As time goes on, the resolution will improve. It'll give us a start on the global geo-chemistry pattern. The second Global Surveyor in 1998 and the third in 2001 will give us that map and examine the atmosphere and climate, in addition. They'll also search for water in the atmosphere, on the surface and just below the surface. These two orbiters will also complete the orbital communications network of three orbiters going around Mars. Our landed missions will use the network to communicate back to Earth.

Building global maps from orbit is our first task. Our second task is to scout selected areas on the Martian surface with landers and rovers using information we obtained from the orbiters. We'll need to examine the local conditions, rock and soil types, the potential for water and other resources and signs of the planet's history. We'll send a series of small, low-cost landers to many different areas of Mars. Then we'll determine the one or two sites we'll go to, to actually bring back samples. The first of our landed missions is Mars Pathfinder '96, which is now call Sojourner. It was named by a young lady in the audience. Will you stand up so we can recognize you? There she is. She was selected out of 3,500 people who submitted suggestions. It was wonderful. She read her essay last night.

Let me talk about the first of our landed missions. There will be a micro-rover to provide mobility on the surface. Pathfinder is only the first. We'll send similar landed missions in '98, 2001 and 2003. [I might point out that the Russians are also sending a robot in '96. We have a payload on their lander in '96 and they have a payload on our lander in '98.] The landed missions we'll do in '98, 2001 and 2003 will go to places as diverse as ancient cratered highlands and the planet's poles. Landers will analyze soil and rocks. One of the things that this will give us is ground truths for orbital remote sensing measurements. The landers may also drill below the surface to better understand the geological history of Mars and search for permafrost. When this phase in our robotics mission is complete, look at what we will have done. We will have embarked on the search for clues to Martian ancient history and its present environment. We'll have searched for signs of past water and geological activities. We'll have looked for signs of minerals that will tell us the story of ancient water and life on Mars. We'll send more landers in 2005. They'll be part of a large international effort to place a network of landers on the surface of Mars. This includes a network of seismometers to understand the interior of Mars and a network of weather stations to understand Martian weather and climate. Imagine getting a weather report from the polar station on Mars on the 11 o'clock news every night.

We want to pave the way to go to Mars. After we finish scouting the global diversity of the Mars surface with small landers, we'll be ready for a sample return mission. That could happen as early as 2005, maybe even as early as 2003. Also by then, we hope the Mars Surveyor program will involve Europe, Japan, France, Russia, Germany and other countries on planet Earth so we could all go to Mars together. A sample return is just the beginning. We'll need ways to move around on the planet. We're looking at a range of things, from micro-rovers like the Pathfinder to larger ones built with the Russians for larger area coverage. We're looking at super pressure balloons and specialized -- I don't want to use the word aircraft, but I couldn't say "Marscraft" because the air is different on Mars. What I mean is a power flight instead of just a balloon. Another possibility is a hopper technique with rockets. We're also interested in micro-landers weighing only a few kilograms each and costing less than a million dollars each. They could be deployed on approach to Mars or from orbit. They could be sharp-pointed to penetrate the soil upon landing and could carry micro-cameras and put micro seismometers and weather stations on a chip on the surface of Mars. The possibilities are fascinating.

However we do this phase of exploration, one thing is certain. We should involve many more people than the scientists and engineers on the payroll. We should and will involve the American public. People will see on their televisions what our rovers see on the surface of Mars. People of all ages and backgrounds, all over the world, will fly with a balloon across the Martian surface. They'll look out over the Martian landscape like they were in a jet liner flying over Earth. But better than that, we're going to be doing scientific analysis in high schools and colleges. Science will not be only for NASA employees and our contractors, but it'll be for students around the world. I want to tell you these young kids want this. This is the beginning of the future. We're already doing it now in high schools around the country. They're helping us with Mission to Planet Earth in Inglewood, California.

The pinnacle of the Mars robotics exploration program will be sample return. We'll do this all efficiently and cheaply. The Mars Pathfinder is about 5% of the cost of Viking. In today's dollars, Viking would be over 3 billion dollars. Pathfinder will cost 270 million dollars. The Mars Global Surveyor will cost about 250 million, not the nearly one billion dollars the Mars Observer cost. But we're not stopping there. The President's budget for 1996 proposed the New Millennium program. It is the object of this program, by the turn of the century, to make spacecraft 10 times cheaper, 10 times faster, 10 times better. We can do it.

Now, let's fast forward into the next century and see what robots could be doing in future times. The most exciting thing they could do is search for the areas where it's possible that life or traces of it might have existed. These fossils could be hidden within certain geological formations. The robots will have to seek out the right outcrops, guided by the mapping done by earlier orbiters. They could also do things to prepare humans for landing on Mars. We could send a robot fuel production plant to Mars. We could send it as early as 2005. The international Mars I crew could use the fuel made on Mars to explore the planet. The fuel production plant sucks in Martian atmosphere and spews out rocket fuel as breathing gas. The fuel would be stored on tanks on the surface of Mars. We could also plant a radio beacon right next to the tanks for the astronauts to home in on as they approach Mars. Robots could be doing many more things to prepare for the astronauts. They could be building a water and wastewater recycling station the size of a barn. They could begin to build the first infrastructure, the first cityscape on Mars. A convoy of robots could map Mars. They'd drill to find where high probability areas exist for water, hydrogen, metals, minerals and other resources to get ready to zero the humans in on these locations. Let me say a word about the search for water. We already know we can obtain limited quantities of water on Mars. We can get it from the atmosphere or at the polar ice caps, but there may be -- just maybe -- aquifers below the surface with liquid water or ice.

There could also be a mobile laboratory, along with these robots. This is where they could deposit soil or rock samples for analysis. Slowly, the profile for the area where the robots are working would emerge. Computers would use the data to build a three-dimensional map. This would be a tomographic map or thermal map of the subsurface of Mars. The robots would develop a picture of the subsurface structure -- layers of rock, the presence of water or ice, the thickness of sediments. Through chemical and seismic and mineralogic analysis, they could determine what the crust is made of. Why are certain types of rocks and minerals present? And why are others that we find on Earth not there?

As we move toward launching the human mission in 2018, here's what we'll have accomplished. Our scientific exploration will have done detailed surveys of sites we want humans to examine for subtle, hard-to-find evidence of life. We'll have scoured the surface to find out where water and other resources are most accessible. When we've found the best sites and studied them with more robots, the world -- and I emphasize the world -- will send the first human beings to the planet Mars. We'll also have figured out how human beings can live and work in space for long periods, and do many other functions. We'll learn much of this aboard the international Space Station. In the process, we'll benefit the people of Earth. That's part of the new-think at NASA.

Let's fast-forward a little further ahead. It's 2018, just moments before the Mars I takes off on its two-year mission. It will take them six or seven months to get to Mars. They'll spend 30 days on the surface, and they'll take 14 or 15 months to get back. Right now, they're on the launch pad. When they get to low-Earth orbit, they'll transfer to the Mars vehicle. Once they're aboard, they'll talk to Mission Control in Houston. They'll also talk to Operation Centers in Kaliningrad, Bavaria and Tsukuba. Before they blast off, let's take a moment. Let's look at what it's taken to get them to this point.

Before we send people into space for several years, we will have had to develop effective countermeasures to micro- and partial gravity. This would have tremendous benefits for the elderly people suffering from diseases such as osteoporosis on Earth. We'll also have developed pre-screening procedures to try to ensure a healthy crew. By the year 2018, that could have led to the ability to identify medical conditions long before the symptoms become overt, so preventative measures can be used. Think about the effects of this on Earth. Think about what it would mean if we could identify and counteract a predisposition for disease. Clearly, that will not solve the whole problem. But we have a need to go to Mars to do this work and learn.

What if our astronauts do get sick on their trip? They won't be able to take hospitals or doctors with them in huge quantities. So we will have had to develop chemical surgery techniques that can heal without scalpels or incisions. We could put micro-machines into their bodies. Doctors could manipulate them from the ground. Back in the 1990s, these little machines were only a concept in the minds of engineers and scientists at NASA and NIH. In 2018, they could monitor what's happening in the body. They could carry antibodies directly to a certain part of the body. They could go to where a problem is and they begin to fix it. That will have made health care on Earth more accessible, cheaper, and less intrusive than it's ever been. The same kind of vital sensors we inject under the skin of astronauts to monitor, diagnose and treat them from the ground could be used throughout the world. They could be used by surgeons to make prenatal corrections. They could be used to continually monitor the elderly. If something goes wrong, a doctor could be on the phone or another interactive system within minutes. People in rural areas in the United States and remote villages around the world could have access to low cost, high-quality health care. We could be diagnosed and treated in our homes. A hospital stay would be the exception.

And, of course, we'll have a new rocket. It'll be a single-stage, not a three-stage rocket. Our single-stage, reusable vehicle will open up the space frontier.

NASA won't have developed it and won't run it -- industry will. Together, industry, government and academia will be opening the space frontier. Entrepreneurs will be building industrial parks in space. The international Space Station won't be alone. It'll be just one in a constellation, along with, perhaps, some stations on the surface of the Moon. Our spaceship will be self-diagnosing and self-repairing. Its systems will incorporate micro- and nano-electrical, electronic, and mechanical technology. It will use the most advanced expert decision-making systems to detect and report problems and do simple fixes. Our astronauts are taking along robotic assistants. They're capable of autonomous operation for exploration, science, and rescue tasks. They're controlled by advanced interfaces like voice recognition. They can see, think, and hear.

By 2018, we'll have done a much better job of integrating people and machines. We will have had to compensate for humans' limitations in absorbing and monitoring information. The Mars crew will need this kind of help because people on the ground won't be able to talk to them in real time. There's a more than 10-minute time lapse in getting a message from Mars to Earth and back. We won't have thousands in Mission Control like we did on the Moon Shot. It'll just be a few astronauts onboard that spacecraft, integrated with the expert decision-making machines. Our crew will have to be able to absorb complex information quickly and make instant decisions without connectivity with Mission Control.

I've taken you billions of years back in time and we've gone to 2018, where Mars I sits on the launch pad, awaiting take-off. Let's take one more jump. Let's look at what the astronauts could be doing once they arrive on Mars. They have three basic missions to perform. One, they will do things connected with finding past life on Mars. Two, they'll be doing things to support life in the present. And three, they'll be doing things for life on Mars in the future.

Let's start with life in the past. Suppose that robots have located areas that appear highly probable for containing fossil cell life. The next step is for humans to confirm that revolutionary finding. A team of astronauts could explore the outcrop where the fossil was found. They'd carefully select the most promising rocks, which they'll bring back to the base for study. Several of our astronauts could go down into an ancient, dried-out lake bed in the northern plateau to do a core drilling. They'll drill around the edges and into the center. They'll analyze the layers for clues to many things. They may find clues to what the atmosphere was like on Mars billions of years ago or more clues to the earliest forms of life.

The Mars I crew will also worry about life in the present. They'll need to make a place on Mars where humans can survive and grow and do research. They'll also look for Martian life that's survived from ancient times in a subsurface micro oasis. They'll also look for water, more precious than gold. Thanks to the robotics precursor missions, they'll have a good idea where to start. They'll use subsurface, ground-penetrating radar -- kind of a high-tech divining rod. As scientists, they know that finding water would be important in understanding the past climate on Mars. As pioneers, they know it's critical to human survival. The astronauts could also build hothouses. Humans won't go to Mars alone. They'll go as a community of life forms, bringing with them seeds and plants grown on the trip. The studies done at the turn of the century in gravitropism -- the way plants react to gravity -- was an important step in that process. NASA began thinking about that in the '90s. Eventually, we'll develop plants that can grow out in the open. The astronauts also could bring along additional production plants to break down the Martian water into oxygen for breathing and hydrogen to use as fuel.

The third thing our crew could do is look toward life in future. They'll begin to assess whether local or broad-range terraforming is feasible -- whether it's possible for human beings to colonize Mars. They might take an inventory of the planet, much like the U.S. Geological Survey did in the Old West in the late 1800s. The Viking Mission of 1976 literally only scratched the surface of Mars. There's a lot we don't know about Mars. So they could take inventory, building on what the robots have already done. Is all the water that once was on Mars still there, or did some of it or most of it escape into space? If most of it escaped, reconstructing a habitable planet's going to be much more difficult. If it's ice, or trapped in the ground like oil is trapped on Earth, it'll be a lot easier. They could run studies and take measurement to try to determine whether people could live on Mars for long periods. Can people live in one-third gravity with no ill effects? There's no magnetic field on Mars -- is that a barrier to sustaining human presence?

They will also forward the search for planets around other stars. Our Solar System contains four Earth-like planets -- Venus, Earth, Mercury and Mars. By better understanding the evolution of Mars, we'll get a better understanding of how planets in general form and evolve. This will help us in our search for solar systems around other stars. As we search for the nearest stars over the next 10-25 years, we may find a planet. We'll be better able to know whether we've found another Venus, Earth or Mars because of what the Mars II astronauts find.

The next human crew to Mars will stay longer. They could stay for nearly two years. They'll develop permanent habitats and grow a lot of their own food. They'll bring "hopper rockets" that will let them get anywhere on the planet. Someday, there will be a colony on Mars. Humans will live and work on the Red Planet. Someday after that, humankind will hear a brand new sound. A newborn baby's thin wail of life -- the fragile voice of the very first Martian.

Thank you very much.

Remarks Delivered by:
NASA Administrator
Daniel S. Goldin

National Planetary Society
Return to Mars II
Washington, DC
Transcript
7/15/95

Thanks for coming on a hot, sweaty Saturday. I had a lot of trouble just functioning this morning. The program says I'm going to talk about the status of the space program, but I'm getting a little tired of talking about politics. I did that all week long, and this has been a very long week. So what I wanted to do today is talk about the vision. I want to continue the discussion on the vision. This is why I came to NASA.

I started working on the Mars expedition in 1962. It is now 1995. We need to really think about it. We have been working on a vision at NASA. We involved thousands of employees at NASA, the Congress and White House to come up with a vision statement we could publish. We came up with a five-year strategic plan. There are five enterprises. Alan Ladwig is developing a real strategic plan -- 25 years. A five-year strategic plan is totally inadequate. We hope to be sharing the new plan with the general public on the Internet. France Cordova next week will be putting out a new science policy on the Internet to get public comment. The whole purpose of this is to involve the public because the space program does not belong to the NASA employees or contractors or the people who work on our budget. It belongs to you. We have good people at NASA, but sometimes we get so involved in our day-to-day activity that we forget that the American public pays for the space program.

About a year ago, I went to the American Geophysical Union and laid out a challenge. I said, "What should be the next step in space? Put a base on the Moon? Put a research station on an asteroid? Go to Mars? We could build telescopes to search for planets around nearby stars if they exist. What should we be doing?" Three or four months ago, I went to Houston to an AIAA conference which dealt with the bio-medical aspects of space flight. I laid out a little fantasy of what the Mars mission might look like when I gave my speech. Today, what I'd like to do is take the next step and broaden it -- lay out a fantasy using a few fiscal facts, taking a lot of liberty, and make a rough sketch.

We'll look back in time 4 and a half billion years. I'll leave a little fact here and there from some of things we've done and seen through telescopes and talk about what might be on Mars. Then we'll fast forward to the year 2019 to describe what the Mars I mission might be doing. But more important than that, I'll lay the foundation of why we want to go to Mars. Then, I hope to expand upon this. I will show slides. I'm going to try and paint the picture in words.

Normally, I don't like to read speeches, but today I'm going to use it because we're experimenting with words, and I'd like to get a little feedback. So feel free to contact me electronically or directly or, if you're old fashioned like I am, take out a pen and write a note. I'm really interested because it's very important. I have complained to the scientific community that they only write for the highly educated. We need to expand our discussion with the broad American public and people around the world. I see we have a friend here from France. We also have friends here from Russia and other countries. It's important to all of us who deal with public funds to be more explicit. So this is an experiment. If you like the speech, tell me. If you don't like it, don't tell me you don't like it, tell me what you don't like so we can make some notes.

I don't have a lot of time because all I do is run up to the Hill. What I've been telling the Members of Congress lately is that I respectfully disagree with them for the first time. The space program should not be cut more. [Applause]. In my mind, in the last three to five years, every time there was a hiccup in some other budget, we pulled it out of the space program. Fortunately, there was room to cut the budget because we had to become more efficient in what we were doing. We had to become more focused. We had to redirect what we were doing. We had to get out of the operations business. We had to prioritize things. We had to get rid of the overhead. I want to tell you we can lose some activities, but on the other hand, I deeply believe there is intrinsic value in the space program, which the American people believe in.

What could happen in the months and weeks ahead? Maybe we'll have some problems. But deep down, I believe that we can't cut anymore. It's not a question of protecting jobs or this or that. The issue is that we have a program that's stunning -- I mean it's stunning. It takes your breath away. It's a program that's built on near-term activity, and it's a program that goes out 25-50 years. So we're there. Now, saying that, I want to talk about real fun things.

But before I do that, I'd like to give some recognition to some of the people I've had conversations with, who have shaped what I have here. One is Chris McKay, who's now in the Arctic, trying to do some relative planetology experiments to see what happens on Earth and on Mars. I also want to recognize France Cordova, Harry Holloway, Wes Huntress, Jeff Plescia, John Kerridge, Michael Meyer, Bob Zubrin and Diane Ballard. If I missed some, I'm sorry. These are people I've interacted with, and they've had wonderful thoughts about how to present all this.

Before I talk about going to Mars, I want to take you on a trip back in time.

Let's go back to an ancient, violent age, 4 and one-half billion years ago. The Earth and Mars are forming in similar ways. They're red hot, glowing with a boiling lava surface. For over a half billion years, they're bombarded with rocks and metals. There is no life. No living things could withstand the heat and the pounding they're taking. Finally, after 600 million years, 3.9 years ago, the bombardment stopped. The noise and the fury ceased. There's just an occasional splashdown of one of the leftover small planetoids. Both the Earth and Mars have cooled down. Their temperatures are below the boiling point of water. Polar caps are beginning to form. Rain falls continually as the steam in their warm atmospheres begins to condense. This leaves behind thick atmospheres rich in carbon dioxide and nitrogen. The Earth and Mars look very much alike. There are large bodies of water on both planets, formed from water steaming out of volcanoes and from impacting comets. During this period, geological features are developing on Mars that will be important billions of years later.

Large impact craters and basins are forming where sediments will later be deposited and preserved. These areas might later harbor traces or the very essence of life itself. Volcanoes are erupting and emitting water vapor. The heat and water are forming hydrothermal circulation systems that could later generate mineral deposits. These systems could produce environments to sustain life. The intense bombardment by meteorites is forming a thick, loose rock layer, a regolith. In the future, it might be the storehouse of subsurface water or ice. Soon, the Earth will produce the first self-replicating molecule. These molecules will assemble themselves into the first single-cell organism. The long march toward intelligent life on Earth is beginning. The same process on Mars may be going on, but the result may be different. We don't know. The result may have been a life form unlike anything on Earth.

Now let's move forward from 3.9 billion years ago to 3.5 billion years ago. Earth and Mars are beginning to diverge. The evolution of the Earth's surface and the atmosphere is hugely affected by the fact that life has taken a foothold on our home planet. Mars is on a different path. It's just beginning to diverge from Earth. Its evolution is being shaped almost exclusively by geophysical, not biological, processes. Life, if it managed a foothold on Mars, couldn't survive on the surface. Surface life couldn't have withstood the change in climate that's going on on Mars. Mars is too small a planet to trap the heat needed to move its huge crustal plates, and that slows down the renewal of the atmosphere through volcanic action. So the Mars atmosphere begins to thin. The planet becomes dryer, colder. Ice is now the dominant form of water on the surface of Mars and below the surface. Life languishes in shrinking pockets of warmth and the remaining small pockets of liquid water.

Not so on Earth. Life flourishes on its warm, wet surface. On Earth, our fossil records go back 3.5 billion years. They're fossils of algae that were found in Australia. The earliest beginnings of life before that are still a mystery to us. We can't go back any further 3.5 billion years. Earlier relics of life were obliterated by the constant change in the Earth's surface as a result of the tectonic activity. But this may not be the case on Mars. The fossils of chemical evolution, if they exist, could still be there, untouched. Because of the cold, arid climate on Mars, there is little erosion. Mars also appears to lack plate tectonics. So much of the planet's ancient crust is probably preserved. Early life on Mars could have fossilized quickly after dying, just like on Earth. Even when the surface of Mars became hostile to life, it may have become benign to fossils. If a fossil formed on Mars 3.5 billion years ago, it is probably still sitting there today. It may be encased in sedimentary material, just waiting for us to find it. When we begin to dig on Mars, when we look through the layers of its crust, we'll look back through a time machine.

It's widely believed that every living thing on Earth shares a common ancestor -- apparently thermophylic bacteria or heat-loving bacteria. Who knows what we'll find on Mars? We might discover traces of whole new kingdoms of originating life. Maybe we'll learn that the same building blocks of life washed over both planets simultaneously. We could find fossils of cells with elements of proteins similar to what's here on Earth. We might find that one fossilized cell that's the missing link between the planets. We might find actual life -- imagine that. We might find extant life in some specialized environment. It may be just below a few grains in translucent sandstone -- a microscopic greenhouse, as in Antarctica. We may find life buried deep in some of the ancient sediments on Mars. Any of these possibilities would profoundly affect how we think about who we are and why we're here.

Mars may be our next destination in space. Its secrets and what it can tell us about our own planet are intriguing. We've learned from our robotic space travels that it is the likeliest planet that might have developed life. This is the white zone. It also has surface conditions the most like our own here on Earth. If Mars is humankind's next destination, the next launch date might be, or so I'd like to think, 2018. That's when it would take the least amount of energy to launch, over a 20-year period. We have time to plan. We have time to do it right. We have time to figure out how humans can live and work safely and efficiently in space on the international Space Station. We have time to figure out how to perform the mission for an affordable price that will allow a sustained presence in the solar system and not be a one-shot firecracker.

Final preparations need not start in earnest until the end of the first decade of the next century. But we can still make a landing in 2018 if we spend our time getting small amounts done. Our goal should be a sustained presence on Mars and in the solar system and not a one-shot, feel-good spectacular mission. We are interested in emigration, not invasion. During the twenty-fifth anniversary [applause] of Apollo, reporters asked me if I or the President were going to announce a mission to Mars, make a big splash. I said, "That's too easy. A one-shot spectacular is not what we're after."

Now Apollo was, but Apollo met a milestone -- a national need to beat the Soviet Union to the Moon. We did, and I'm proud of it. I participated. It was brute force. We spent 5% of the national budget to make this happen, but we had no vision beyond landing on the Moon so we went into the wilderness for 25 years. We spent 5% of the national budget in today's terms and we did it in 8 years. That would be the equivalent today of spending 75 billion dollars a year in 8 years. This is not what we're about. People have this feel-good feeling about Apollo and say, "Dan, why can't we do it again?" Well, we're spending eight-tenths of one percent of the federal budget -- not 5% -- and we're into a marathon, not a sprint. We're into sustaining a presence in the solar system and in space, not a feel-good thing because we no longer have to beat the Soviet Union. We're going to partner with the Russians, the French, Germans, and Japanese. We don't have that kind of money any more, and that's not all that bad.

The bad news is our budget is cut. The good news is it's forcing us to do things differently, more innovatively, more imaginatively, more cooperatively. We're going to use a new-think on our next piloted missions. We'll leverage 21st century technology. We've come a long way since Apollo, and we don't need brute force any more. We'll work with international partners, industry, government and academia. We'll take the time to develop and apply new technology before building the Mars rockets and equipment. We don't need to have a jobs program to go to Mars, we need to go to Mars. We'll create economic opportunity as we do. We'll develop space. Our rockets won't just take us to Mars, they'll open the space frontier. Unlike Apollo, we'll live off the land. The most successful expeditions in human history didn't try to carry all their supplies with them. Lewis and Clark lived off the land, and that's exactly what we will do. One set of choices is brute force versus technological finesse. We choose technological finesse. Rushing to Mars would be brute force. The use of brawn would drive the cost beyond anything that's tolerable.

Our other set of choices is this. We in the United States can lead the world in this noble venture or we can buy a ticket and just go along. I submit that America is proactive. We should lead and not sit in the grandstands. If we lead the world, we'll shape humankind's boldest adventure. But we have to start now, there's a lot of work to do. We should be pursuing two parallel paths right now. And not only should we do it, we are doing it. These two parallel paths are robotics precursor missions and fundamental missions to understand the rigors of human space flight.

Let me start with the robots. We're entering the second era of scientific, robotic Mars exploration with the Mars Surveyor program. This isn't a one-shot program. We're going to do this thing, then we'll go for another one. We'll take advantage of every window to Mars to send a spacecraft. It's a continuing series of reconnaissance missions to fully explore the planet Mars. We have other missions, but I'm not going to talk about those. I'm going to focus on Mars. We're going to explore Mars carefully, deliberately and systematically. We'll be bold, but not brash. This won't be a sprint mission, this is a marathon. Instead of rushing up to grab the first rock or handful of soil we can, we'll get a better understanding of the planet. We'll figure out where it makes sense to take samples. We'll want to be smart before we go. That way, the samples we do bring back will tell us the most about Martian evolution, climate, water and other resources.

Our first job is to map the planet from orbit. Towards this end, we'll send small, low-cost orbiters to Mars in '96, '98 and 2001 to do that. The first Global Surveyor will be launched in '96 to map the geology and topography of Mars. I'm not really thrilled with the resolution yet because it will give us a broad picture, but as time goes on, the resolution will narrow. It'll give us a start on the global geo-chemistry pattern. The second in 1998 and the third in 2001 will give us that map and examine the atmosphere and climate, in addition. They'll also search for water in the atmosphere on the surface and just below the surface. These two orbiters will also complete the orbital communications network of three orbiters going around Mars. Our landed missions will use the network to communicate back to Earth. We won't have to jerry-rig each mission.

Building global maps from orbit was our first task. Our second task was to scout selected areas on the Martian surface with landers and rovers using information we obtained from the orbiters. We'll need to examine the local conditions, rock and soil types, the potential for water and other resources and signs of the planet's history. We'll send a series of small, low-cost landers to many different areas of Mars. Then we'll determine the one or two sites we'll go to, to actually bring back samples. The first of our landed missions is Mars Pathfinder '96, which is now call Sojourner, due to a young lady in the audience. Will you stand up so we can recognize you? There she is. She was selected out of 3,500 people to apply for this. It was wonderful. She read her essay last night.

Let me talk about the first of our landed missions. There will be a micro-rover to provide mobility on the surface. Pathfinder is only the first. We'll send similar landed missions in '98, 2001 and 2003. I might point out that the Russians are also sending robots over in '96. We have a payload on their lander in '96 and they have a payload on our lander in '98. They will go to places as diverse as ancient cratered highlands and the planet's poles. Landers will analyze soil and rocks. One of the things that will give us is ground truths for remote sensing measurements. The landers may also drill below the surface to better understand the geological history of Mars and search for permafrost.

When this phase in our robotics mission is complete, look at what we will have done. We will have embarked on the search for clues to Martian ancient history and its present environment. We'll have searched for signs of past water and geological activities. We'll have looked for signs of minerals that will tell us the story of ancient water and life on Mars. We'll send more landers in 2003. They'll be part of a large international effort to place a network of landers on the surface of Mars. This includes a network of seismometers to understand the interior of Mars and a network of weather stations to understand Martian weather and climate. Imagine getting a weather report from the polar station on Mars on the 11 o'clock news every night.

We want to pave the way to go to Mars. After we finish scouting the global diversity of the Mars surface with small landers, we'll be ready for a sample return mission. That could happen as early as 2005, maybe even 2003. Also by then, we hope the Mars Surveyor program will involve Europe, Japan, France, Russia, Germany and other countries on planet Earth so we could all go to Mars together. A sample return is just the beginning. We'll need ways to move around on the planet. We're looking at a range of things, from micro-rovers like the Pathfinder to larger ones built with the Russians for larger area coverage. We're looking at super pressure balloons and specialized -- I don't want to use the word aircraft, but I couldn't say "Marscraft" because the gas is different on Mars. What I mean is a power flight instead of just a balloon. We'll do this with very long aerial surveys of the planet. Another possibility is a hopper technique with rockets. We're also interested in micro-landers weighing only a few kilograms each and costing less than a million dollars each. They could be deployed on approach to Mars or from orbit. They could be sharp-pointed to penetrate the soil upon landing and could carry micro-cameras and put micro seismometers and weather stations on a chip on the surface of Mars. The possibilities are fascinating.

However we do this phase of exploration, one thing is certain. We should involve many more people than the scientists and engineers on the payroll. We should and will involve the American public. People will see on their televisions what our rovers see on the surface of Mars. People of all ages and backgrounds, all over the world, will fly with a balloon across the Martian surface. They'll look out over the Martian landscape like they were in a jet liner flying over Earth. But better than that, we're going to be doing scientific analysis in high schools and colleges. Science will not be only for NASA employees and our contractors, but it'll be for students around the world. I want to tell you these young kids want this. This is the beginning of the future. We're already doing it now in high schools around the country. They're helping us with Mission to Planet Earth in Eaglewood, California.

The pinnacle of the Mars robotics exploration program will be sample return. We'll do this all efficiently and cheaply. The Mars Pathfinder is about

5% of the cost of Viking. In today's dollars, Viking would be over 3 billion dollars. Pathfinder will cost 270 million dollars. The Mars Global Surveyor will cost about 250 million, not the nearly one billion dollars the Mars Observer cost. But we're not stopping there. The President's budget for 1996 proposed the New Millennium program. It is the object of this program, by the turn of the century, to make spacecraft 10 times cheaper, 10 times faster, 10 times better. We can do it.

Now, let's fast forward into the next century and see what robots are doing in future times. The most exciting thing they're doing is searching for the areas where it's possible that life or traces of it might have existed. These fossils could be hidden within certain geological formations. The robots have to seek out the right outcrops, guided by the mapping done by earlier orbiters. They're also doing things to prepare humans for landing on Mars. We've sent a robot fuel production plant to Mars. We could send it as early as 2003. The international Mars I crew will use the fuel made on Mars to explore the planet. The fuel production plant sucks in Martian atmosphere and spews out rocket fuel as breathing gas. The fuel is stored on tanks on the surface of Mars. We've planted a radio beacon right next to the tanks for the astronauts to home in on as they approach Mars. Robots will be doing many more things to prepare for the astronauts. They're building a water and waste water recycling station the size of a barn. They're beginning to build the first infrastructure, the first cityscape on Mars. A convoy of robots is mapping Mars. They're drilling to find where high probability areas exist for water, hydrogen, metals, minerals and other resources to get ready to zero the humans in on these locations. Let me say a word about the search for water. We already know we can obtain limited quantities of water on Mars. We can get it from the atmosphere or at the polar ice caps, but there may be -- just maybe -- aquifers below the surface with liquid water or ice.

With these robots is a mobile laboratory, where they'll deposit soil or rock samples for analysis. Slowly, the profile for the area where the robots are working emerges. Computers use the data to build a three-dimensional map. It's a tomographic map or thermal map of the subsurface of Mars. The robots are developing a picture of the subsurface structure -- layers of rock, the presence of water or ice, the thickness of sediments. Through chemical and seismic and mineralogic analysis, they are determining what the crust is made of. Why are certain types of rocks and minerals present? And why are others that we find on Earth not there?

As we move toward launching the human mission in 2018, here's what we'll have accomplished. Our scientific exploration will have done detailed surveys of sites we want humans to examine for subtle, hard-to-find evidence of life. We'll have scoured the surface to find out where water and other resources are most accessible. When we've found the best sites and studied them with more robots, the world -- and I emphasize the world -- will send the first human beings to the planet Mars. We'll also have figured out how human beings can live and work in space for long periods, and do many other functions. We'll learn much of this aboard the international Space Station. In the process, we'll benefit the people of Earth. That's part of the new-think at NASA.

Let's fast-forward a little further ahead. It's 2018, just moments before the Mars I takes off on its two-year mission. It will take them six or seven months to get to Mars. They'll spend 30 days on the surface, and they'll take 14 or 15 months to get back. Right now, they're on the launch pad. When they get to low-Earth orbit, they'll transfer to the Mars vehicle. Once they're aboard, they'll talk to Mission Control in Houston. They'll also talk to Operation Centers in Kaliningrad, Bavaria and Tsukuba. Before they blast off, let's take a moment. Let's look at what it's taken to get them to this point.

Before we send people into space for several years, we had to develop effective countermeasures to micro- and partial gravity. That had tremendous benefits for the elderly people suffering from diseases such as osteoporosis on Earth. We developed pre-screening procedures to try to ensure a healthy crew. We can now identify medical conditions long before the symptoms become overt, so preventative measures can be used. Think about the effects of this on Earth. Think about what it would mean if we could identify and counteract a predisposition for cancer. Clearly, that will not solve the whole problem. But we have a need to go to Mars to do this work and learn.

What if our astronauts do get sick on their trip? They can't take hospitals or doctors with them in huge quantities. So we had to develop chemical surgery techniques that can heal without scalpels or incisions. We could put micro-machines into their bodies. Doctors will manipulate them from the ground. Back in the 1990s, these little machines were only a concept in the minds of engineers and scientists at NASA and NIH. In 2018, they monitor what's happening in the body. They carry antibodies directly to a certain part of the body. They go to where a problem is and they begin to fix it. That's made health care on Earth more accessible, cheaper, and less intrusive than it's ever been. The same kind of vital sensors we put into the bodies of astronauts to monitor, diagnose and treat them from the ground are used throughout the world. They're used by surgeons to make prenatal corrections. They're used to continually monitor the elderly. If something goes wrong, a doctor is on the phone or another interactive system within minutes. People in rural areas in the United States and remote villages around the world have access to low cost, high-quality health care. We're diagnosed and treated in our homes. A hospital stay is now the exception.

And, of course, we have a new rocket. It's a single-stage, not a 52-stage rocket. Our single-stage, reusable vehicle is opening up the space frontier. NASA didn't develop it and doesn't run it -- industry does. Together, industry, government and academia are opening the space frontier. Entrepreneurs are building industrial parks in space. The international Space Station isn't alone. It's just one in a constellation, along with, perhaps, some stations on the surface of the Moon. Our spaceship is self-diagnosing and self-repairing. Its systems incorporate micro- and nano-electrical, electronic, and mechanical technology. It uses the most advanced expert decision-making systems to detect and report problems and do simple fixes. Our astronauts are taking along robotic assistants. They're capable of autonomous operation for exploration, science, and rescue tasks. They're controlled by advanced interfaces like voice recognition. They can see, think, and hear.

By 2018, we'll have done a much better job of integrating people and machines. We had to compensate for humans' limitations in absorbing and monitoring information. The Mars crew needs this kind of help because people on the ground won't be able to talk to them in real time. There's a more than 10-minute time lapse in getting a message from Mars to Earth and back. We won't have thousands in Mission Control like we did on the Moon Shot. It'll just be a few astronauts onboard that spacecraft, integrating the expert decision-making machines. Our crew will have to be able to absorb complex information quickly and make instant decisions without connectivity with Mission Control.

I've taken you billions of years back in time and we've gone to 2018, where Mars I sits on the launch pad, awaiting take-off. Let's take one more jump. Let's look at what the astronauts do once they arrive on Mars. They have three basic mission to perform. One, they will do things connected with finding past life on Mars. Two, they'll be doing things to support life in the present. And three, they'll be doing things for life on Mars in the future.

Let's start with life in the past. Suppose that robots have located areas that appear highly probable for containing fossil life. The next step is for humans to confirm that revolutionary finding. A team of astronauts is exploring the outcrop where the fossil was found. They are carefully selecting the most promising rocks, which they'll bring back to the base for study. Several of our astronauts have gone down into an ancient, dried-out lake bed in the Northern pole to do a core drilling. They'll drill around the edges and into the center. They'll analyze the layers for clues to many things. The may find clues to what the atmosphere was like on Mars billions of years ago or more clues to the earliest forms of life.

The Mars I crew is also worrying about life in the present. They're making a place on Mars where humans can survive and grow and do research. They're also looking for Martian life that's survived from ancient times in a subsurface micro oasis. They're also looking for water, more precious than gold. Thanks to the robotics precursor missions, they have a good idea where to start. They're using subsurface, ground-penetrating radar -- kind of a high-tech divining rod.

As scientists, they know that finding water would be important in understanding the past climate on Mars. As pioneers, they know it's critical to human survival. The astronauts are also building hothouses. Humans didn't go to Mars alone. They went as a community of life forms, bringing with them seeds and plants grown on the trip. The studies done at the turn of the century in gravitropism -- the way plants react to gravity -- was an important step in that process. NASA began thinking about that in the '90s. Eventually, we'll develop plants that can grow out in the open. They also brought additional production plants to break down the Martian water into oxygen for breathing and hydrogen to use as fuel.

The third thing our crew is doing is looking toward life in future. They're beginning to assess whether global or broad-range terraforming is feasible -- whether it's possible for human beings to colonize Mars. They're taking an inventory of the planet, much like the U.S. Geological Survey did in the Old West in the late 1800s. The Viking Mission of 1976 literally only scratched the surface of Mars. There's a lot we don't know about Mars. So they're taking inventory, building on what the robots have already done. Is all the water that once was on Mars still there, or did some of it or most of it escape into space? If most of it escaped, reconstructing a habitable planet's going to be much more difficult. If it's ice, or trapped in the ground like oil is trapped on Earth, it'll be a lot easier. They're running studies and taking measurement to try to determine whether people could live on Mars for long periods. Can people live in one-third gravity with no ill effects? There's no magnetic field on Mars -- is that a barrier to sustaining human presence?

They're also forwarding the search for planets around other stars. Our Solar System contains three Earth-like planets -- Venus, Earth and Mars. By better understanding the evolution of Mars, we'll get a better understanding of how planets in general form and evolve. This will help us in our search for solar systems around other stars. As we search for the nearest stars over the next 10-25 years, we may find a planet. We'll be better able to know whether we've found another Venus, Earth or Mars because of what the Mars II astronauts have found.

The next human crew to Mars will stay longer. They'll stay for nearly two years. They'll develop permanent habitats and grow a lot of their own food. They'll bring "hopper rockets" that will let them get anywhere on the planet. Someday, there will be a colony on Mars. Humans will live and work on the Red Planet. Someday after that, humankind will hear a brand new sound. A newborn baby's thin wail of life -- the fragile voice of the very first Martian.

Thank you very much.

7-15-95

Return to Mars II

sedimentation

→ large catastrophic flood channels flowing north 30°N mat'l deposited at base of lake or ocean near low lying

(Asymmetric North latitudes lower in elevation 4-5k southern highlands northern lowlands

→ if studying body limestones $CaCO_3$ detect at impact craters see subsurface seen in ejecta will mine out lower layers use different size craters see depth.

remote sense of ejecta

→ metamorphic

earth hydrothermal yellowstone get concentrations metal ores

were volcanos / water did it last long enough

SNC meteorites - suggest significant active volcanism 180M years ago. 1 B 1.3 K 2 B years ago big volcanos 2B - 0.5B from present.

4.5 → 3.9B bombardment stop

build atmosphere, semi liquid crust. (Did big meteors blow away atmosphere)

3.9B → 3.5B make water lake

Water came out of ground & flowed (same process water out of volcanos placed in ground by rainfall)

3.5B started to diverge (always on slightly different path

smaller
less heat
less radioactivity)

no crustal plate motion to renew volcanic activity plate techtonics recycle crust

mid Atlantic ridge new crust forms

edge pacific South Amer
Asia goes back in

destroyed ancient crust

Australia 3.5B
~~austria~~ 2.0B
canada

more heat on earth
~~mantle~~ more trapped heat from accretion
more radio

convection at mantle hot stuff rises cold stuff falls

Mid atlantic hot

engine not vigorous enough

Mars lost water at top of atmosphere $H_2O \rightarrow H_2 + O_2$
H_2 escapes lower mass faster

Mars didn't retrieve CO_2 + H_2O recirculates gases on surface.

gases from volcano

carbonates good for preserving fossils

If not alot of carbonate no atmosphere
can't find carbonate recently

found in SNC meteorites

volcanism died out cooled

NA Africa 1cm apart each year
mid atlantic process keeps atmosphere sustained

less of loss rate from upper atmosphere

plates at subduction zone
eliminates volatiles at downwelling

Aleutians
Andes
cascades) subduction volcanoes

craters in path of channels
smaller basins (southern highlands)
in addition to northern lowlands
(large standing bodies, 100's km)
~1 km deep.

if life ever formed
$CaCO_3$ fixed fossils —
since no subduction

3.5B Australian rocks
high % organic stuff
+ microfossils. (proven on earth)
no example because rocks don't exist

igneous rock

metamorphic heated fuses
tectonic activity

hydrothermal vent will generate
minerals not metamorphic
great to preserve organisms

mineral grains grow quickly
~~catch organisms get trapped~~ kept as
decays in death put in solid in dike
ancient form
n hydrothermal vent near flank
of volcanos

in vent or lake.

x yellowstone algae mixed in
silica

x petrified forest Arizona
logs in volcanic ash
silica replaced cellulose
hot water water silica acting

Co Tom Gold

all for hydrothermal circulation

frequency hydrothermal vents
to the lower — much less
volcanic activity

water volcanic activity
interface

hydrothermal activity $\propto$ volcanic activity

need 100M to hydrothermal vent
3km

strategy for looking for life

Viking big one shot like apollo

now measured series
focus in on that one
rock with fossil.

Lugest Grand Prizmatic 30~100m
hydrothermal vent diameter

Thermal
Emission
Spectrometer
TES

2 → 15 μ

3km

Water

minerals with water
on surface TES

① physically in pool

for rock ② chemically tied up in
mineral

(
atmosphere has water
all water few μ thick
→ clouds & frost at ~~poles~~poles
)

that left etc

poles water ice
permanent water ice cap
seasonal ~~water~~ CO_2 cap

below surface
water ice
liquid water

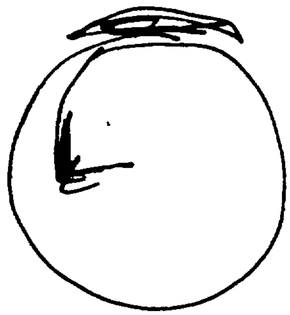
---

dry zone
frozen ice
liquid water water

perhaps
in pores
of lakes

could have aquifers on Mars
rubble zone fr impacts
porosity for water

outside



ice 2km

at 45° latitude 1km below
to have ice

(1) isolate areas
northern lowlands 10-20° → pole

(2) seismic experiments on surface

(3) hollows/wires

water + energy source (chemical / thermal energy)

build condensation plant suck
out of atmosphere.

- don't know where to look for life?
- climatic history on mars?

→ sample return for ground truth? compare to earth
do on surface?

---

drilled deep wells on earth
Taylorsville basin
~ 100's meter below surface
rocks 230M years old
find bacteria brought fr depth.
speculate those bacteria isolated fr surface for 230M years.

hydrogen flux might be energy source,

Thermophilic bacteria
(heat loving bacteria)
(life evolved in hot spring
and/or survivor from last big impact)

Trace back in genetic material in DNA
Tree of molecular relationships

— ? not oldest
but closely related
to oldest
[illegible].

100km resolution
could identify characteristics

venus clouds

mars try cold

1000m picture earth/mars
fundamental geology

mars current
earth young

craters
crustal
recycling

heat data

~~(craters~~
~~oceans)~~
~~mountain chains~~
~~clouds~~

Titan thermal
form clouds

Resources devoted to
instrument technology

7-15-95
Return to Mars II

Search for NASA Vision
- Vision statement
- strategic plan ~~5~~ yrs. → 25 years
- Enterprise operationing
- Science Policy

- AIAA speech in Houston
Biomedical conference

- fantasy voyage ~~to~~ of Mars II and tasks required leading up to that voyage

Today I am taking the next step to expand on the vision of future planetary exploration. My goal is to help America visualize where the space program is going and why we must open the space frontier.

I ask your indulgence since my thoughts are not fully together. Over the months ahead I intend to continue to expand on these thoughts to make it understandable to the broad range of American people. I would appreciate any feedback on content or ~~[illegible]~~ wording.

If we are to open the space frontier it is crucial that we ~~involve~~ engage people in all walks of life in America and around the world.

In this paper I will paint a picture of what formation of the planets ~~earth~~ & mars might have been and what we might expect to further. This picture is based on a projection of our limited observations of mars.

I will then paint a vision of how we might begin robotic exploration of mars

Remarks Delivered by:
NASA Administrator
Daniel S. Goldin

Steps to Mars

National Planetary Society
Return to Mars II
Washington, DC
Transcript
7/15/95

Today, I want to paint a picture of some of the possibilities for humankind in space. I want to take you on a fantasy journey to Mars, where we'll see robots building the first cityscape on Mars and astronauts searching for signs of early life.

Before I talk about going to Mars, I want to take you on a trip back in time. Let's go back to an ancient, violent age, 4 and one-half billion years ago. The Earth and Mars are forming in similar ways. They're red hot, glowing with a boiling lava surface. For over a half billion years, they're bombarded with rocks and metals. There is no life. No living things could withstand the heat and the pounding they're taking. Finally, after 600 million years, 3.9 years ago, the bombardment stops. The noise and the fury cease. There's just an occasional splashdown of one of the leftover small planetoids. Both the Earth and Mars have cooled down. Their temperatures are below the boiling point of water. Polar caps are beginning to form. Rain falls continually as the steam in their warm atmospheres begins to condense. This leaves behind thick atmospheres rich in carbon dioxide and nitrogen. The Earth and Mars look very much alike. There are large bodies of water on both planets, formed from water steaming out of volcanoes and from impacting comets. During this period, geological features are developing on Mars that will be important billions of years later.

Large impact craters and basins are forming where sediments will later be deposited and preserved. These areas might later harbor traces or the very essence of life itself. Volcanoes are erupting and emitting water vapor. The heat and water are forming hydrothermal circulation systems that could later generate mineral deposits. These systems could produce environments to sustain life. The intense bombardment by meteorites is forming a thick, loose rock layer, a regolith. In the future, it might be the storehouse of subsurface water or ice. Soon, the Earth will produce the first self-replicating molecule. These molecules will assemble themselves into the first single-cell organism. The long march toward intelligent life on Earth is beginning. The same process on Mars may be going on, but the result may be different. We don't know. The result may have been a life form unlike anything on Earth.

Now let's move forward from 3.9 billion years ago to 3.5 billion years ago. Earth and Mars are beginning to diverge. The evolution of the Earth's surface and the atmosphere is largely affected by the fact that life has taken a foothold on our home planet. Mars is on a different path. It's just beginning to diverge from Earth. Its evolution is being shaped almost exclusively by geophysical, not biological, processes. Life, if it managed a foothold on Mars, couldn't survive on the surface. Surface life couldn't have withstood the change in climate on Mars. Mars is too small a planet to trap the heat needed to move its huge crustal plates, and that slows down the renewal of the atmosphere through volcanic action. So the Mars atmosphere begins to thin. The planet becomes dryer, colder. Ice is now the dominant form of water on the surface of Mars and below the surface. Life languishes in shrinking pockets of warmth and the remaining small pockets of liquid water.

Not so on Earth. Life flourishes on its warm, wet surface. On Earth, our fossil records go back 3.5 billion years. They're fossils of algae that were found in Australia. The earliest beginnings of life before that are still a mystery to us. We can't go back any further 3.5 billion years. Earlier relics of life were obliterated by the constant change in the Earth's surface as a result of the tectonic activity. But this may not be the case on Mars. The fossils of chemical evolution, if they exist, could still be there, untouched. Because of the cold, arid climate on Mars, there is little erosion. Mars also appears to lack plate tectonics. So much of the planet's ancient crust is probably preserved. Early life on Mars could have fossilized quickly after dying, just like on Earth. Even when the surface of Mars became hostile to life, it may have become benign to fossils. If a fossil formed on Mars 3.5 billion years ago, it is probably still sitting there today. It may be encased in sedimentary material, just waiting for us to find it. When we begin to dig on Mars, when we look through the layers of its crust, we'll look back through a time machine.

It's widely believed that every living thing on Earth shares a common ancestor -- apparently thermophylic bacteria or heat-loving bacteria. Who knows what we'll find on Mars? We might discover traces of whole new kingdoms of originating life. Maybe we'll learn that the same building blocks of life washed over both planets simultaneously. We could find fossils of cells with elements of proteins similar to what's here on Earth. We might find that one fossilized cell that's the missing link between the planets. We might find actual life -- imagine that. We might find extant life in some specialized environment. It may be just below a few grains in translucent sandstone -- a microscopic greenhouse, as in Antarctica. We may find life buried deep in some of the ancient sediments on Mars. Any of these possibilities would profoundly affect how we think about who we are and why we're here.

Mars may be our next destination in space. Its secrets and what it can tell us about our own planet are intriguing. We've learned from our robotic space travels that it is the likeliest planet that might have developed life. This is the life zone. It has surface conditions the most like our own here on Earth. If Mars is humankind's next destination, the next launch date could be 2018. That's when it would take the least amount of energy to launch, over a 20-year period. We have time to plan. We have time to do it right. We have time to figure out how humans can live and work safely and efficiently in space on the international Space Station. We have time to figure out how to perform the mission for an affordable price that will allow a sustained presence in the solar system and not be a one-shot firecracker.

Final preparations need not start in earnest until the end of the first decade of the next century. But we can still make a landing in 2018 if we begin laying the groundwork now. Our goal should be a sustained presence on Mars and in the solar system and not a one-shot, feel-good spectacular mission. We are interested in emigration, not invasion. During the twenty-fifth anniversary [applause] of Apollo, reporters asked me if I or the President were going to announce a mission to Mars, make a big splash. I said, "That's too easy. A one-shot spectacular is not what we're after."

Now, Apollo was a one-shot sprint mission, but Apollo also met a national need -- beating the Soviet Union to the Moon. We did that, and I'm proud of it. I participated. It was brute force. We spent about 5% of the national budget to make this happen, but we had no vision beyond landing on the Moon so we went into the wilderness for 25 years. The program spent 5% of the national budget in today's terms and we did it in 8 years, which would be the equivalent today of spending 75 billion dollars a year in 8 years. This is not what we're about. People have this feel-good sense about Apollo and say, "Dan, why can't we do it again?" Well, now we're investing eight-tenths of one percent of the federal budget -- not 5% -- and we're into a marathon, not a sprint. We're into sustaining a presence in the solar system and in space, not a feel-good thing because we no longer have to beat the Soviet Union. We're going to partner with the Russians, the French, Germans, Japanese and others. We don't have that kind of money any more, and that's not all that bad.

The bad news is our budget is cut. The good news is it's forcing us to do things differently, more innovatively, more imaginatively, more cooperatively. We're going to use a new-think on our next piloted missions. We'll leverage 21st century technology. We've come a long way since Apollo, and we don't need brute force any more. We'll work with international partners, industry, government and academia. We'll take the time to develop and apply new technology before building the Mars rockets and equipment. We don't need to have a jobs program to go to Mars, we need to go to Mars. We'll create economic opportunity as we do. We'll develop space. Our rockets won't just take us to

Mars, they'll open the space frontier. Unlike Apollo, we'll live off the land. The most successful expeditions in human history didn't try to carry all their supplies with them. Lewis and Clark lived off the land, and that's exactly what we will do. One set of choices is brute force versus technological finesse. We choose technological finesse. Rushing to Mars would be brute force. The use of brawn would drive the cost beyond anything that's tolerable.

Our other choice is this -- we in the United States can lead the world in this noble venture or we can buy a ticket and just watch. I submit that America is proactive. We should lead and not sit in the grandstands. If we lead the world, we'll shape humankind's boldest adventure. But we have to start now, there's a lot of work to do. We should be pursuing two parallel paths right now, and that's exactly what we're doing. These two parallel paths are robotics precursor missions and fundamental missions to understand the rigors of human space flight.

Let me start with the robots. We're entering the second era of scientific, robotic Mars exploration with the Mars Surveyor program. This isn't a one-shot program. We'll take advantage of every window to Mars to send a spacecraft. It's a continuing series of reconnaissance missions to fully explore the planet Mars. We have other missions, but I'm not going to talk about those. I'm going to focus on Mars. We're going to explore Mars carefully, deliberately and systematically. We'll be bold, but not brash. This won't be a sprint mission, this is a marathon. Instead of rushing up to grab the first rock or handful of soil we can, we'll get a better understanding of the planet. We'll figure out where it makes sense to take samples. We'll want to be smart before we go. That way, the samples we do bring back will tell us the most about Martian evolution, climate, water and other resources.

Our first job is to map the planet from orbit. Towards this end, we'll send small, low-cost orbiters to Mars in '96, '98 and 2001 to do that. The first Global Surveyor will be launched in '96 to map the geology and topography of Mars. I'm not really thrilled with the spatial resolution yet, but it will give us a broad picture. As time goes on, the resolution will improve. It'll give us a start on the global geo-chemistry pattern. The second Global Surveyor in 1998 and the third in 2001 will give us that map and examine the atmosphere and climate, in addition. They'll also search for water in the atmosphere, on the surface and just below the surface. These two orbiters will also complete the orbital communications network of three orbiters going around Mars. Our landed missions will use the network to communicate back to Earth.

Building global maps from orbit is our first task. Our second task is to scout selected areas on the Martian surface with landers and rovers using information we obtained from the orbiters. We'll need to examine the local conditions, rock and soil types, the potential for water and other resources and signs of the planet's history. We'll send a series of small, low-cost landers to many different areas of Mars. Then we'll determine the one or two sites we'll go to, to actually bring back samples. The first of our landed missions is Mars Pathfinder '96, which is now call Sojourner. It was named by a young lady in the audience. Will you stand up so we can recognize you? There she is. She was selected out of 3,500 people who submitted suggestions. It was wonderful. She read her essay last night.

Let me talk about the first of our landed missions. There will be a micro-rover to provide mobility on the surface. Pathfinder is only the first. We'll send similar landed missions in '98, 2001 and 2003. [I might point out that the Russians are also sending a robot in '96. We have a payload on their lander in '96 and they have a payload on our lander in '98.] The landed missions we'll do in '98, 2001 and 2003 will go to places as diverse as ancient cratered highlands and the planet's poles. Landers will analyze soil and rocks. One of the things that this will give us is ground truths for orbital remote sensing measurements. The landers may also drill below the surface to better understand the geological history of Mars and search for permafrost. When this phase in our robotics mission is complete, look at what we will have done. We will have embarked on the search for clues to Martian ancient history and its present environment. We'll have searched for signs of past water and geological activities. We'll have looked for signs of minerals that will tell us the story of ancient water and life on Mars. We'll send more landers in 2005. They'll be part of a large international effort to place a network of landers on the surface of Mars. This includes a network of seismometers to understand the interior of Mars and a network of weather stations to understand Martian weather and climate. Imagine getting a weather report from the polar station on Mars on the 11 o'clock news every night.

We want to pave the way to go to Mars. After we finish scouting the global diversity of the Mars surface with small landers, we'll be ready for a sample return mission. That could happen as early as 2005, maybe even as early as 2003. Also by then, we hope the Mars Surveyor program will involve Europe, Japan, France, Russia, Germany and other countries on planet Earth so we could all go to Mars together. A sample return is just the beginning. We'll need ways to move around on the planet. We're looking at a range of things, from micro-rovers like the Pathfinder to larger ones built with the Russians for larger area coverage. We're looking at super pressure balloons and specialized -- I don't want to use the word aircraft, but I couldn't say "Marscraft" because the air is different on Mars. What I mean is a power flight instead of just a balloon. Another possibility is a hopper technique with rockets. We're also interested in micro-landers weighing only a few kilograms each and costing less than a million dollars each. They could be deployed on approach to Mars or from orbit. They could be sharp-pointed to penetrate the soil upon landing and could carry micro-cameras and put micro seismometers and weather stations on a chip on the surface of Mars. The possibilities are fascinating.

However we do this phase of exploration, one thing is certain. We should involve many more people than the scientists and engineers on the payroll. We should and will involve the American public. People will see on their televisions what our rovers see on the surface of Mars. People of all ages and backgrounds, all over the world, will fly with a balloon across the Martian surface. They'll look out over the Martian landscape like they were in a jet liner flying over Earth. But better than that, we're going to be doing scientific analysis in high schools and colleges. Science will not be only for NASA employees and our contractors, but it'll be for students around the world. I want to tell you these young kids want this. This is the beginning of the future. We're already doing it now in high schools around the country. They're helping us with Mission to Planet Earth in Inglewood, California.

The pinnacle of the Mars robotics exploration program will be sample return. We'll do this all efficiently and cheaply. The Mars Pathfinder is about 5% of the cost of Viking. In today's dollars, Viking would be over 3 billion dollars. Pathfinder will cost 270 million dollars. The Mars Global Surveyor will cost about 250 million, not the nearly one billion dollars the Mars Observer cost. But we're not stopping there. The President's budget for 1996 proposed the New Millennium program. It is the object of this program, by the turn of the century, to make spacecraft 10 times cheaper, 10 times faster, 10 times better. We can do it.

Now, let's fast forward into the next century and see what robots could be doing in future times. The most exciting thing they could do is search for the areas where it's possible that life or traces of it might have existed. These fossils could be hidden within certain geological formations. The robots will have to seek out the right outcrops, guided by the mapping done by earlier orbiters. They could also do things to prepare humans for landing on Mars. We could send a robot fuel production plant to Mars. We could send it as early as 2005. The international Mars I crew could use the fuel made on Mars to explore the planet. The fuel production plant sucks in Martian atmosphere and spews out rocket fuel as breathing gas. The fuel would be stored on tanks on the surface of Mars. We could also plant a radio beacon right next to the tanks for the astronauts to home in on as they approach Mars. Robots could be doing many more things to prepare for the astronauts. They could be building a water and wastewater recycling station the size of a barn. They could begin to build the first infrastructure, the first cityscape on Mars. A convoy of robots could map Mars. They'd drill to find where high probability areas exist for water, hydrogen, metals, minerals and other resources to get ready to zero the humans in on these locations. Let me say a word about the search for water. We already know we can obtain limited quantities of water on Mars. We can get it from the atmosphere or at the polar ice caps, but there may be -- just maybe -- aquifers below the surface with liquid water or ice.

There could also be a mobile laboratory, along with these robots. This is where they could deposit soil or rock samples for analysis. Slowly, the profile for the area where the robots are working would emerge. Computers would use the data to build a three-dimensional map. This would be a tomographic map or thermal map of the subsurface of Mars. The robots would develop a picture of the subsurface structure -- layers of rock, the presence of water or ice, the thickness of sediments. Through chemical and seismic and mineralogic analysis, they could determine what the crust is made of. Why are certain types of rocks and minerals present? And why are others that we find on Earth not there?

As we move toward launching the human mission in 2018, here's what we'll have accomplished. Our scientific exploration will have done detailed surveys of sites we want humans to examine for subtle, hard-to-find evidence of life. We'll have scoured the surface to find out where water and other resources are most accessible. When we've found the best sites and studied them with more robots, the world -- and I emphasize the world -- will send the first human beings to the planet Mars. We'll also have figured out how human beings can live and work in space for long periods, and do many other functions. We'll learn much of this aboard the international Space Station. In the process, we'll benefit the people of Earth. That's part of the new-think at NASA.

Let's fast-forward a little further ahead. It's 2018, just moments before the Mars I takes off on its two-year mission. It will take them six or seven months to get to Mars. They'll spend 30 days on the surface, and they'll take 14 or 15 months to get back. Right now, they're on the launch pad. When they get to low-Earth orbit, they'll transfer to the Mars vehicle. Once they're aboard, they'll talk to Mission Control in Houston. They'll also talk to Operation Centers in Kaliningrad, Bavaria and Tsukuba. Before they blast off, let's take a moment. Let's look at what it's taken to get them to this point.

Before we send people into space for several years, we will have had to develop effective countermeasures to micro- and partial gravity. This would have tremendous benefits for the elderly people suffering from diseases such as osteoporosis on Earth. We'll also have developed pre-screening procedures to try to ensure a healthy crew. By the year 2018, that could have led to the ability to identify medical conditions long before the symptoms become overt, so preventative measures can be used. Think about the effects of this on Earth. Think about what it would mean if we could identify and counteract a predisposition for disease. Clearly, that will not solve the whole problem. But we have a need to go to Mars to do this work and learn.

What if our astronauts do get sick on their trip? They won't be able to take hospitals or doctors with them in huge quantities. So we will have had to develop chemical surgery techniques that can heal without scalpels or incisions. We could put micro-machines into their bodies. Doctors could manipulate them from the ground. Back in the 1990s, these little machines were only a concept in the minds of engineers and scientists at NASA and NIH. In 2018, they could monitor what's happening in the body. They could carry antibodies directly to a certain part of the body. They could go to where a problem is and they begin to fix it. That will have made health care on Earth more accessible, cheaper, and less intrusive than it's ever been. The same kind of vital sensors we inject under the skin of astronauts to monitor, diagnose and treat them from the ground could be used throughout the world. They could be used by surgeons to make prenatal corrections. They could be used to continually monitor the elderly. If something goes wrong, a doctor could be on the phone or another interactive system within minutes. People in rural areas in the United States and remote villages around the world could have access to low cost, high-quality health care. We could be diagnosed and treated in our homes. A hospital stay would be the exception.

And, of course, we'll have a new rocket. It'll be a single-stage, not a three-stage rocket. Our single-stage, reusable vehicle will open up the space frontier. NASA won't have developed it and won't run it -- industry will. Together, industry, government and academia will be opening the space frontier. Entrepreneurs will be building industrial parks in space. The international Space Station won't be alone. It'll be just one in a constellation, along with, perhaps, some stations on the surface of the Moon. Our spaceship will be self-diagnosing and self-repairing. Its systems will incorporate micro- and nano-electrical, electronic, and mechanical technology. It will use the most advanced expert decision-making systems to detect and report problems and do simple fixes. Our astronauts are taking along robotic assistants. They're capable of autonomous operation for exploration, science, and rescue tasks. They're controlled by advanced interfaces like voice recognition. They can see, think, and hear.

By 2018, we'll have done a much better job of integrating people and machines. We will have had to compensate for humans' limitations in absorbing and monitoring information. The Mars crew will need this kind of help because people on the ground won't be able to talk to them in real time. There's a more than 10-minute time lapse in getting a message from Mars to Earth and back. We won't have thousands in Mission Control like we did on the Moon Shot. It'll just be a few astronauts onboard that spacecraft, integrated with the expert decision-making machines. Our crew will have to be able to absorb complex information quickly and make instant decisions without connectivity with Mission Control.

I've taken you billions of years back in time and we've gone to 2018, where Mars I sits on the launch pad, awaiting take-off. Let's take one more jump. Let's look at what the astronauts could be doing once they arrive on Mars. They have three basic missions to perform. One, they will do things connected with finding past life on Mars. Two, they'll be doing things to support life in the present. And three, they'll be doing things for life on Mars in the future.

Let's start with life in the past. Suppose that robots have located areas that appear highly probable for containing fossil cell life. The next step is for humans to confirm that revolutionary finding. A team of astronauts could explore the outcrop where the fossil was found. They'd carefully select the most promising rocks, which they'll bring back to the base for study. Several of our astronauts could go down into an ancient, dried-out lake bed in the northern plateau to do a core drilling. They'll drill around the edges and into the center. They'll analyze the layers for clues to many things. They may find clues to what the atmosphere was like on Mars billions of years ago or more clues to the earliest forms of life.

The Mars I crew will also worry about life in the present. They'll need to make a place on Mars where humans can survive and grow and do research. They'll also look for Martian life that's survived from ancient times in a subsurface micro oasis. They'll also look for water, more precious than gold. Thanks to the robotics precursor missions, they'll have a good idea where to start. They'll use subsurface, ground-penetrating radar -- kind of a high-tech divining rod. As scientists, they know that finding water would be important in understanding the past climate on Mars. As pioneers, they know it's critical to human survival. The astronauts could also build hothouses. Humans won't go to Mars alone. They'll go as a community of life forms, bringing with them seeds and plants grown on the trip. The studies done at the turn of the century in gravitropism -- the way plants react to gravity -- was an important step in that process. NASA began thinking about that in the '90s. Eventually, we'll develop plants that can grow out in the open. The astronauts also could bring along additional production plants to break down the Martian water into oxygen for breathing and hydrogen to use as fuel.

The third thing our crew could do is look toward life in future. They'll begin to assess whether local or broad-range terraforming is feasible -- whether it's possible for human beings to colonize Mars. They might take an inventory of the planet, much like the U.S. Geological Survey did in the Old West in the late 1800s. The Viking Mission of 1976 literally only scratched the surface of Mars. There's a lot we don't know about Mars. So they could take inventory, building on what the robots have already done. Is all the water that once was on Mars still there, or did some of it or most of it escape into space? If most of it escaped, reconstructing a habitable planet's going to be much more difficult. If it's ice, or trapped in the ground like oil is trapped on Earth, it'll be a lot easier. They could run studies and take measurement to try to determine whether people could live on Mars for long periods. Can people live in one-third gravity with no ill effects? There's no magnetic field on Mars -- is that a barrier to sustaining human presence?

They will also forward the search for planets around other stars. Our Solar System contains four Earth-like planets -- Venus, Earth, Mercury and Mars. By better understanding the evolution of Mars, we'll get a better understanding of how planets in general form and evolve. This will help us in our search for solar systems around other stars. As we search for the nearest stars over the next 10-25 years, we may find a planet. We'll be better able to know whether we've found another Venus, Earth or Mars because of what the Mars II astronauts find.

The next human crew to Mars will stay longer. They could stay for nearly two years. They'll develop permanent habitats and grow a lot of their own food. They'll bring "hopper rockets" that will let them get anywhere on the planet. Someday, there will be a colony on Mars. Humans will live and work on the Red Planet. Someday after that, humankind will hear a brand new sound. A newborn baby's thin wail of life -- the fragile voice of the very first Martian.

Thank you very much.

Acknowledgment: Special thanks to the talented people who helped give me a vision for this fantasy trip to Mars. One of them is Chris McKay, who's now in the Arctic doing relative planetology experiments to better understand what happened on Mars and what it means to the evolution of our own planet. I also want to thank France Cordova, Harry Holloway, Wes Huntress, Jeff Plescia, John Kerridge, Michael Meyer, Bob Zubrin and Diane Ballard.

Dan Goldin

Steps To Mars II

July 15, 1995

I want to start by thanking several of the people who contributed to this paper. I spoke with a lot of people in my search for a vision -- and a picture -- of the Mars journey.

I want to thank Chris McKay. I also want to thank some very talented people at NASA:

France Cordova,
Harry Holloway,
Wes Huntress,
Jeff Plescia,
John Kerridge,
and Michael Meyer.

Before I talk about going to Mars, I want to take you on a trip back in time. Let's go back to an ancient, violent age, 4-and-a-half billion years ago.

The Earth and Mars are forming in similar ways. They're red-hot, glowing with a boiling lava surface. For over a half billion years, they're bombarded with rocks and metals. There is no life. No living thing could withstand the heat and the pounding they're taking.

Finally, 3.9 billion years ago, the bombardment stops. The noise and the fury cease. There's just an occasional splashdown of one of the left-over small planetismals.

Both the Earth and Mars have cooled down. Their temperatures are below the boiling point of water. Polar caps are beginning to form. Rain falls continually as the steam in their warm atmospheres condense. This leaves behind thick atmospheres rich in carbon dioxide and nitrogen.

Earth and Mars look very much alike. There are large bodies of water on both planets, formed from water steaming out of volcanoes and from impacting comets.

During this period, geologic features are developing on Mars that will be important billions of years later. Large impact craters and basins are forming, where sediments will later be deposited and preserved. These areas might later harbor traces of life, or life itself.

Volcanoes are erupting and emitting water vapor. The heat and water are forming hydrothermal circulation systems that could later generate metal mineral deposits. These systems could produce environments for life.

The intense bombardment by meteorites is forming a thick, loose rock layer -- a regolith. In the future, it might be the storehouse of subsurface water and ice.

Soon, the Earth will produce the first self-replicating molecules. These will assemble themselves into the first single-cell organisms. The long march toward intelligent life on Earth will begin.

The same process on Mars may be going on. But the result may be different. The result may have been a life form unlike anything we have on Earth.

Let's move forward from 3.9 billion years ago to 3.5.

Earth and Mars are beginning to diverge. The evolution of the Earth's surface and atmosphere is hugely affected by the fact that life has a foothold on the planet.

Mars is on a different path. Its evolution is being shaped almost exclusively by geophysical processes. Life, if it managed a foothold on Mars, couldn't survive on the surface. Surface life couldn't have withstood the change in climate. Mars is too small a planet to trap the heat needed to move its huge crustal plates. That slows down the renewal of the atmosphere through volcanic action.

So the Mars atmosphere begins to thin. The planet becomes dryer and colder. Ice is now the dominant form of water on the surface of Mars and below. Life languishes in shrinking pockets of warmth and liquid water.

Not so on Earth. Life flourishes on its warm, wet surface. On Earth, our fossil records go back 3-and-a-half billion years. They're fossils of algae that were found in Australia. The earliest beginnings of life before that are a mystery. We can't go back any further than 3-and-a-half billion years. Earlier relics of life were obliterated by constant change on the Earth surface.

That may not be the case on Mars. The fossils of chemical evolution -- if they exist

-- could still be there. Because of the cold, arid climate of Mars, there is little erosion. Mars also lacks plate tectonics. So much of the planet's ancient crust has been preserved.

Early life on Mars could have fossilized quickly after dying, just like on Earth. But even when the surface of Mars became hostile to life, it remained benign for fossils. A fossil formed on Mars 3-and-a-half billion years ago is probably still sitting there. It may be encased in sedimentary rock, waiting for us to find it.

When we begin to dig on Mars, when we look through the layers of its crust, we'll look back through time.

It's widely believed that every living thing on Earth shares a common ancestor -- apparently, thermophyllic sulfur bacteria. Who knows what we'll find on Mars? We might discover traces of whole new kingdoms of life.

Maybe we'll learn that the same building blocks of life washed over both planets. We could find fossils of cells with elements of proteins similar to what's here on Earth. We could find that one fossilized cell that's the missing link between the two planets.

We might find actual life -- imagine that. We might find extant life in some specialized environment. It may be just below a few grains in translucent sandstone -- a microscopic greenhouse, as in Antarctica. We may find life buried deep in ancient sediments.

Any of these possibilities would be profound.

Mars may be our next destination in space. Its secrets, and what it could tell us about our own planet are intriguing. We've learned from our robotic travels that Mars is the likeliest planet to have developed life. It also has surface conditions the most like our own.

If Mars is humankind's next destination, we should launch in 2018. That's when it would take the least amount of energy to launch. We have time to plan. We have time to do it right.

Our goal should be a sustained presence on Mars, not a one-shot, spectacular mission. Emigration, not invasion.

During the 25th anniversary of Apollo, reporters asked me if I was going to announce a mission to Mars -- make a big splash. I said, "That's too easy." A one-shot spectacular isn't what we're after.

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We'll create economic opportunity on our way. We will develop space. Our rockets won't just take us to Mars. They'll open up the space frontier.

Unlike Apollo, we'll live off the land. The most successful expeditions on Earth didn't try to carry all their supplies with them. Lewis and Clark lived off the land, and that's what we'll do.

One set of choices is brute force versus sophistication. Brawn versus brains.

The other set of choices is this. We can lead the world, or we can sit on the sidelines and watch. Whether we go or not, Japan will be there in 30 years.

If we lead the world, we'll shape humankind's boldest adventure. But we have to start now. There is a lot of work to do. We should be pursuing two parallel paths right now. Robotic precursor missions, and human space flight.

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Instead of rushing up to grab any rock or handful of soil we can, we'll get a better understanding of the planet. We'll figure out where it makes sense to take samples. We want to be smart before we go. That way, the samples we do bring back will tell us the most about Martian evolution, climate, water and other resources.

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Landers will analyze soil and rocks. One of the things that will give us is ground truths for remote sensing measurements.

The landers may also drill below the surface and look for permafrost.

When this phase of our robotic missions is complete, look at what we'll have done. We will have embarked on the search for clues to Martian ancient history and its present environment. We'll have searched for signs of past water and geological activity. We'll have looked for minerals that will tell us the story of ancient water and life.

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People will see on their televisions what our rovers see on the surface of Mars. People of all ages and backgrounds all over the world will fly with a balloon across the Martian surface. They'll look out over the Martian landscape like they were in a jet liner flying over the Earth.

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The most exciting thing they're doing is searching for life or traces of it. These fossils could be hidden within certain geological formations. The robots first have to seek out the right outcrops, guided by the mapping done earlier by orbiters.

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As we move toward launching the human mission in 2018, here's what we'll have accomplished.

Our scientific exploration will have done detailed surveys of sites we want humans to examine for subtle and hard-to-find evidence of life. We'll have scoured the surface to find out exactly where water and other resources are most accessible.

When we've found the best sites and studied them with robots, the world will send the first human beings to the planet Mars.

We'll also have figured out how human beings can live and work in space for long periods, and many other things. We'll learn much of this aboard the international Space Station. In the process, we'll benefit the people on Earth. That's part of the new-think at NASA.

Let's fast-forward a little further ahead. It's 2018, just moments before the Mars I crew takes off for their two-year mission. It will take them six or seven months to get to Mars. They'll spend 30 days on the planet's surface. And they'll take 14 or 15 months to get back.

Right now, they're on the launch pad. When they get to low-Earth orbit, they'll transfer to the Mars vehicle. Once they're aboard, they'll talk to Mission Control in Houston. They'll also talk to Operation Centers in Kaliningrad, Bavaria and Tsukuba.

Before they blast off, let's take a moment. Let's look at what it's taken to get them to this point.

Before we send people into space for several years, we had to develop effective countermeasures to microgravity. That had tremendous benefits for elderly people suffering from osteoporosis on Earth.

We developed pre-screening procedures, to try to ensure a healthy crew. We can now identify medical conditions long before the symptoms become overt, so preventative measures can be used. Think about the effects of that on Earth. Think about what it would mean if we could identify and counteract a predisposition for cancer.

What if our astronauts do get sick on their trip? They can't take hospitals or doctors with them. So we had to develop chemical surgery techniques that can heal without scalpels or incisions. We put micro-machines into their bodies. Doctors will manipulate them from the ground.

Back in the 1990s, these little machines were only a concept in the minds of engineers and scientists at NASA and NIH. In 2018, they monitor what's happening in the body. They carry antibodies directly to a certain part of the body. They go to where a problem's begun and fix it.

That's made health care on Earth more accessible, cheaper, and less intrusive than it's ever been. The same kind of vital sensors we put into the bodies of astronauts to monitor, diagnose and treat them from the ground are used throughout the world.

They're used by surgeons to make prenatal corrections. They're used to continually monitor the elderly. If something goes wrong, a doctor is on the phone or another interactive system within minutes. People in rural areas in the United States and remote villages around the world have access to high-quality health care. We're diagnosed and treated in our homes. A hospital stay is the exception.

Of course we have a new rocket. Our reusable launch vehicle is opening up space. NASA doesn't run it -- industry does. Together, industry, government and academia are developing space.

Entrepreneurs are building industrial parks in space. The international Space Station isn't alone. It's just one in a constellation.

Our spaceship is self-diagnosing and self-repairing. Its systems incorporate micro- and nano-technology. It uses artificial intelligence to detect and report problems, and do simple fixes.

Our astronauts are taking along robotic assistants. They're capable of autonomous operation for exploration, science, and rescue tasks. They're controlled by advanced interfaces like voice recognition.

By 2018, we'll have done a much better job of integrating people and machines. We had to compensate for humans' limitations in absorbing and monitoring information. The Mars crew needs this kind of help because people on the ground won't be able to talk to them in real time. There's a more than 10-minute time lapse in getting a message from Mars to Earth and back.

Our crew will have to be able to absorb complex information quickly and make instant decisions.

I've taken you billions of years back in time. We've gone into the future to 2018, where Mars I sits on the launch pad, awaiting take-off. Let's take one more jump. Let's look at what the astronauts do once they arrive on Mars.

They're doing three kinds of activities.

One, they're doing things connected with past life on Mars. Two, they're doing things to support life in the present. And three, they're doing things for life in the future.

Let's start with life in the past. Suppose that robots have found a rock with what looks like a fossil in it. The next step is for humans to confirm that revolutionary finding. A team of astronauts is exploring the outcrop where the fossil was found. They are carefully selecting the most promising looking rocks, which they'll bring back to the base for study.

Several of our astronauts have gone down into an ancient, dried-out lake bed in the Southern Hemisphere to do a core drilling. They'll drill around the edges and into the center. They'll analyze the layers for clues to many things. The may find clues to what the atmosphere was like on Mars billions of years ago. Or more clues to the earliest forms of life.

The Mars I crew is also worrying about life in the present. They're making a place on Mars where humans can survive and grow and do research. They're also looking for Martian life, that's survived from ancient times, in a subsurface oasis.

They're also looking for water, more precious than gold. Thanks to the robotic precursor missions, they have a good idea where to start.

They're using subsurface, ground-penetrating radar -- kind of a high-tech divining rod. As scientists, they know that finding water would be important in understanding the past climate of Mars. As pioneers, they know it's critical to human survival.

The astronauts are also building hothouses. Humans didn't go to Mars alone. They went as a community of life forms, bringing with them seeds and plants grown on the trip. The studies done at the turn of the century on gravitropism -- the way plants react to gravity -- was an important step in the process. Eventually, we'll develop plants that can grow out in the open.

They also brought additional production plants to break down the Martian water into oxygen for breathing and hydrogen to use as fuel.

The third thing our crew is doing is looking toward life in future. They're beginning to assess whether terraforming is feasible. Whether it's possible for human beings to colonize Mars.

They're taking an inventory of the planet, much like the U.S. Geological Survey did in the Old West in the late 1800s.

Viking literally only scratched the surface. There's a lot we don't know about Mars. So they're taking inventory, building on what the robots have already done.

Is all the water that once was on Mars still there, or did some of it escape into space? If most of it escaped, reconstructing a habitable planet's going to be harder. If it's ice, or trapped in the ground, like oil is trapped on Earth, it'll be easier.

They're running studies and taking measurement to try to determine whether people could live on Mars for long periods.

Can people live in one-third gravity with no ill effects? There's no magnetic field on Mars -- is that important?

They're also forwarding the search for planets around other stars. Our Solar System contains three Earth-like planets -- Venus, Earth and Mars. By better understanding the evolution of Mars, we'll get a better understanding of how planets in general form and evolve. This will help us in our search for solar systems around other stars.

As we search for the nearest 100 stars over the next 10 or 15 years, we may find a planet. We'll be better able to know whether we've found another Venus, Earth or Mars because of what our Mars I astronauts learn.

The next human crew to Mars will stay longer. They'll stay for nearly two years. They'll develop permanent habitats and grow a lot of their own food. They'll bring "hopper rockets" that will let them get anywhere on the planet.

Someday, there will be a colony on Mars. Humans will live and work on the Red Planet.

Someday after that, humankind will hear a brand new sound. A newborn baby's thin wail of life -- the fragile voice of the very first Martian.

Thank you.